U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

NOAA Technical Memorandum NWS SR-68

WEATHER SURVEILLANCE BY AIR ROUTE TRAFFIC CONTROL RADAR

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SOUTHERN REGION HEADQUARTERS
SCIENTIFIC SERVICES DIVISION
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I. INTRODUCTION

The primary reason for any weather radar program is to effect the collection, analysis and dissemination of radar weather information. The ideal situation would be to install strategically located, highly sophisticated weather surveillance radars (WSR-57) throughout the entire country. However, to accomplish this would involve a great number of very expensive radars and is economically unsound.

The idea of utilizing Air Route Traffic Control Center (ARTCC) radars for weather purposes had been advanced many times and in 1966, the National Weather Service (NWS) and the Federal Aviation Administration (FAA) began a joint-use program for collection of weather intelligence using radars monitored at the Salt Lake City ARTCC. The unqualified success of this program and the economy which it represented led to the establishment of similar operations at the Palmdale, California center in 1968, the Albuquerque, New Mexico center in 1969, and the Seattle, Washington center in 1970. Twenty-one ARTC radars are now being monitored by Weather Radar Specialists. This paper describes the operations and capabilities of the Albuquerque unit.

A. ORGANIZATION The joint NWS/FAA radar unit at Albuquerque is under the administrative and technical supervision of the Meteorologist in Charge of the Weather Service Forecast Office (WSFO) located approximately fifteen miles away. Responsibility for the radar unit rests with a Supervisory Radar Meteorologist.

B. RADAR LOCATIONS The inauguration of the Albuquerque operation brought into play six very high powered radars located near Amarillo and El Paso, Texas; Tucumcari, Albuquerque, and Silver City, New Mexico; and Phoenix, Arizona. (Future plans include the addition of two radars located near Gallup, New Mexico and Quartzsite, Arizona). These radars provide weather surveillance over portions of several states and northern Mexico that heretofore contained vast areas for which little or no weather information was available (figure 1).

C. PHYSICAL LAYOUT OF FACILITY The Albuquerque Center is housed in a building standard for most ARTC Centers (figure 2) where, in the main control room, aircraft control, flight data, and communication personnel and equipment are located (figure 3). The maintenance equipment is located below the main control room and houses six fourteen-inch PPI radar scopes (figure 4) and seven-inch Scan Converter scopes (figure 5). These scopes are made available for use by NWS personnel whose office is in the same area (figures 6 and 7). In addition to the above equipment, a radar console is located in the weather office. From this fourteen-inch PPI scope, all six radars can be monitored by selecting the desired radar display in much the same way as selecting television channels.

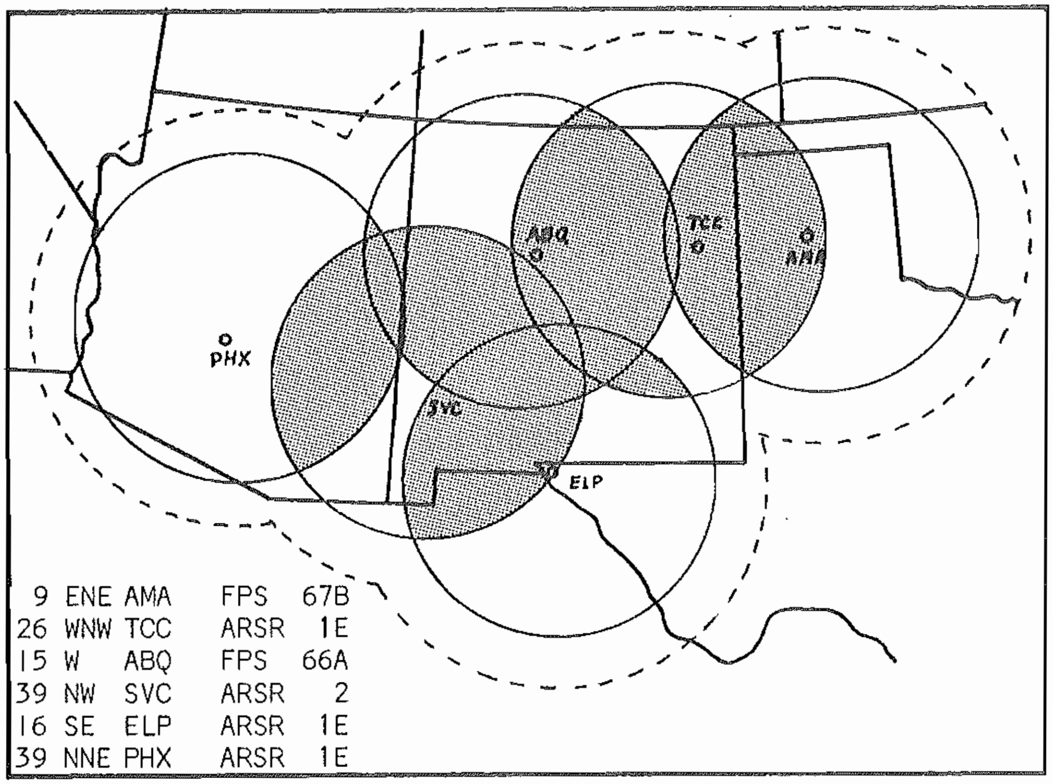


Figure I. Type, location and range limits of Albuquerque Air Route Traffic Control Center radars. Solid circles show 150 nmi effective range (and overlap); dashed outline shows maximum range limits.

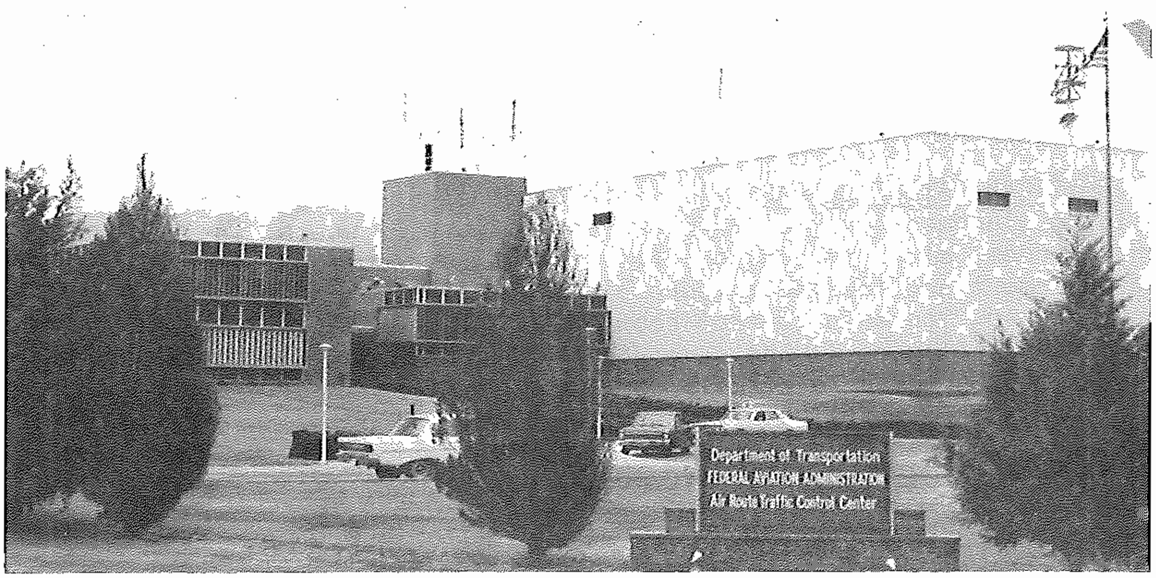


Figure 2. Albuquerque Air Route Traffic Control Center.

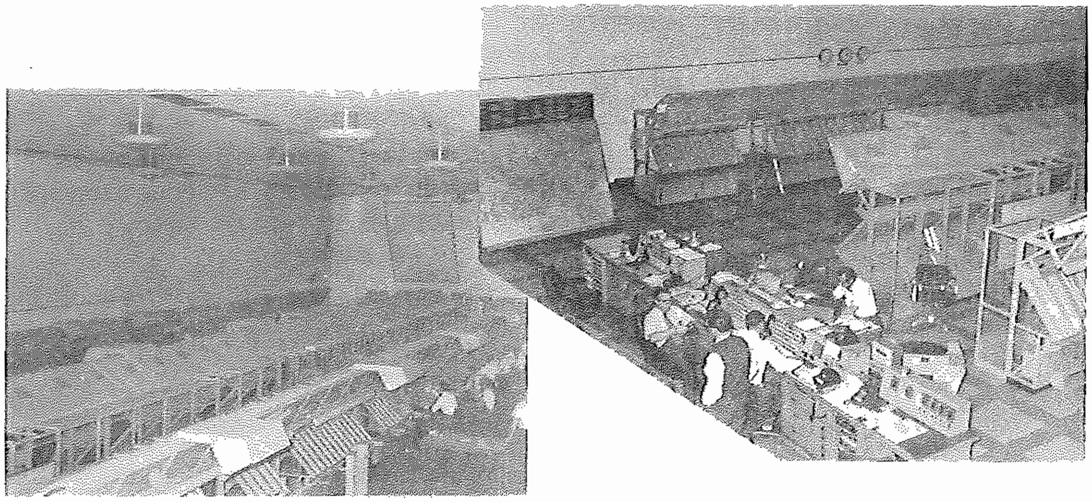


Figure 3. Two views of Albuquerque ARTC Center

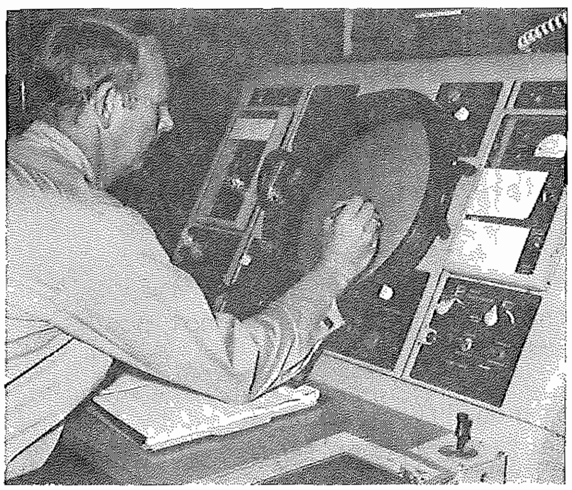


Figure 4. One of Six Scopes in Equipment Room

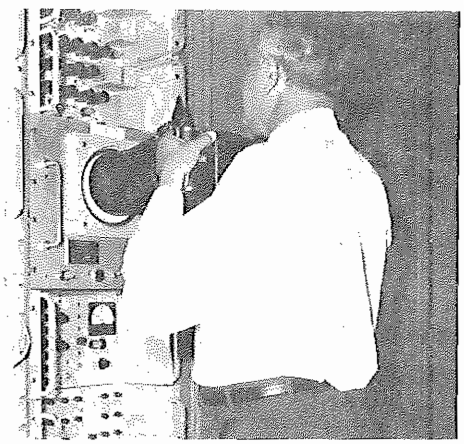


Figure 5. Maintenance Scan Converter Scope

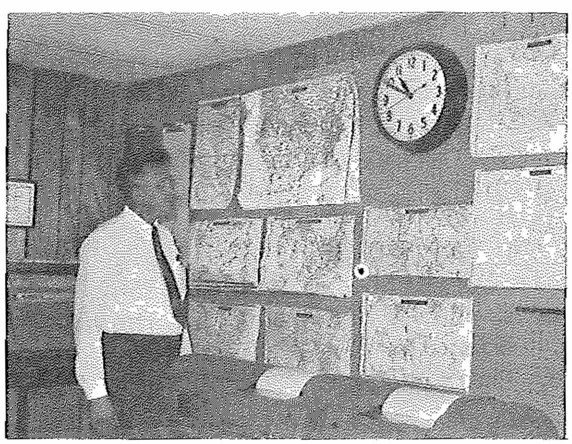
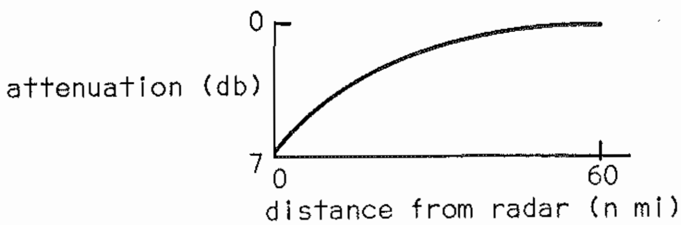


Figure 6. Weather Office Briefing Display

Figure 7. Weather Office Facsimile Transmission

II. CHARACTERISTICS OF THE ARTC RADARS

A. <u>SENSITIVITY TIME CONTROL (STC)</u> STC on the FAA-ARTC radars is used to suppress ground clutter. At the radar site 7db attenuation is added. This gradually diminishes along the curve as shown below, so that at 60 n mi (or 700 μs) the attenuation is zero.



B. <u>MOVING TARGET INDICATOR (MTI)</u> MTI is another technique for eliminating or minimizing clutter caused by reflections from objects on the ground. MTI circuits operate on the principle that stationary targets will be of the same amplitude and at the same distance from pulse to pulse. On this basis, if a return pulse is stored from one pulse to another the succeeding pulse can be inverted and used to cancel the preceding one. If the target is moving the cancellation will not occur since the pulses will not occur at the same time.

The clutter caused by precipitation cannot readily be eliminated by MTI circuitry due to the movement of the elements or echoes themselves and the motion of the particles within them. This does not seem to pose any great problem since light rain is invariably seen within the MTI gate. Therefore the standard techniques for eliminating rain clutter are to operate the radar at a low frequency and to utilize circular polarization, rather than using MTI.

C. <u>CIRCULAR POLARIZATION (CP)</u> This is a mode of radar transmitter operation in which the electric field of the Radio Frequency (RF) Energy is of a special nature so as to give a minimum reflection from spherical objects such as rain drops.

D. <u>COMPARATIVE CHARACTERISTICS OF WSR-57 AND FAA RADARS</u> The basic characteristics of the WSR-57, the Air Route Surveillance Radar (ARSR) and the Fixed Pulse System (FPS) radars are compared in Table 1. The symbols used in the NAFAX Radar Reports for both the FAA-ARTC radars and the WSR-57 are shown on the NAFAX Radar Chart Legend. (Page 6)

TABLE 1

RADAR CHARACTERISTICS

	WSR-57[1]	ARSR-1D,-1E,-2[2]	FPS-66A & 67B[3]
Wave Length	10 cm	23 cm	23 cm
Peak Power	500 kw	5000 or 500 kw[4]	3000 kw
Antenna Gain	39.0 db	34.0 db	35 db
Pulse Length	4 μs	2 μs	6 μs
Minimum Detectable Signal	-103 dbm	-112 dbm	-112 dbm
PRF	164 pps	360 pps	360 pps
Range	250 n mi	200 n mi	200 n mi
Horizontal Beam width Θ (half-power points)	2.0°	1.4°	1.4°
Vertical Beam width Φ	2.0°	6.2°	6.2°
Polarization	Linear	Linear & Circular	Linear & Circular

1. Characteristics of the WSR-57 are based on manufacturers specifications and measurements with test equipment at NSSL. The NWS calibrates to -103 dbm.

2. The ARSR-1E is the same as the ARSR-1D with a parametric amplifier added to lower the MDS. The ARSR-2 differs from the ARSR-1D and 1E only by having refined receiver circuits to lessen noise. Characteristics of the ARSR type radars are based on manufacturers specifications and measurements by FAA.

3. The FPS-66A and FPS-67B are essentially the same and differ very little from the FPS-20. They do differ from the ARSR type, i.e., by switching arrangement, they have the capability of having circular polarization in either the vertical or horizontal plane and right or left circular polarized.

4. With amplitron "on" the output power is 5 megawatts and with it "off" (magnetron "on") the output power is 500 KW.

RADAR SUMMARY CHART LEGEND

U.S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator
NATIONAL WEATHER SERVICE
George P. Cressman, Director

GENERAL

Two methods of data depiction appear on these charts. East of the Rockies radar reports are plotted and grouped in certain configurations. West of the Rockies, actual echo patterns from ARTC radar sites are shown. Most of the symbols used are common to both sections of the map.

SURFACE WEATHER ASSOCIATED WITH ECHOES

T	Thunderstorm	IP	Ice Pellets
R	Rain	L	Drizzle
RW	Rain Showers	ZR	Freezing Rain
S	Snow	ZL	Freezing Drizzle
SW	Snow Showers	A	Hail

PRECIPITATION INTENSITY

— —	Very Light	+	Heavy
—	Light	+ +	Very Heavy
No Sign	Moderate	U	Unknown

Intensity of echoes is given in terms of the estimated precipitation intensity. No intensity is ascribed to drizzle, hail, sleet or snow. Echoes located farther than a specified range, usually 125 nautical miles, are given an intensity of unknown or "U".

INTENSITY TREND

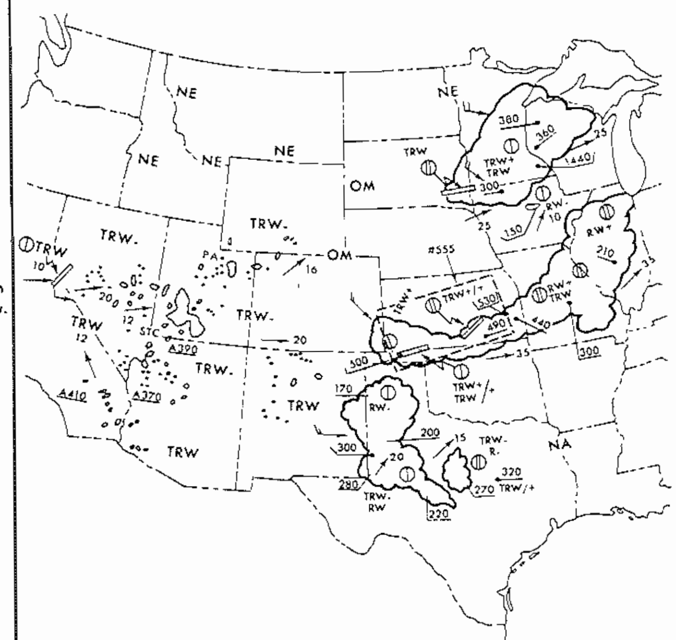
\+ Increasing NEW New Development
— Decreasing

Intensity trend follows the precipitation intensity and is preceded by a slash mark. The absence of a symbol means that there has been no change in the intensity.

STATUS OF EQUIPMENT

NE No echoes
NA Observation not available
OM Equipment out for maintenance
CP Moderate to strong echoes reported only
STC Reduced detection capability within 30 miles of radar
MAG Radar on reduced power
Last three items from ARTC reports only

SAMPLE RADAR SUMMARY CHART
WW NR 555 Valid Til 0200Z



MOTION OF ECHOES

V V Cell Movement - Speed in knots
Area or line movement--(10 kts/barb)
LM Little movement

ECHO HEIGHTS

hhh Height of echo tops
hhh Height of maximum reported echo top
hhh Height of echo bases
hhh Height of melting level
Ahhh Visual cloud top seen by aircraft
Heights are in hundreds of feet MSL.

CHARACTER OF ECHOES

Area of echoes
Line of echoes
Solid — Coverage within area or line is greater than 9 tenths
Broken — Coverage within area or line is greater than 5 tenths but not greater than 9 tenths
Scattered — Coverage within area or line is not greater than 5 tenths and not less than one tenth
Widely Scattered — Coverage within area or line is less than one tenth
Strong or very strong cell identified by one station
Strong or very strong cell identified by two or more stations
Actual echo boundary copied from ARTC scopes
PA Partly Aloft
MA Mostly Aloft
Layers aloft associated with other echoes will be preceded by acronym for partly aloft or mostly aloft

Severe Weather Watch area with entry of number and valid time of watch.

JUNE 1972

III. COMPARISON OF THE WSR-57 AND THE FPS-67B RADARS AT AMARILLO,TEXAS

The capability of air route surveillance radars to provide valuable meteorological information has been amply demonstrated. In 1964, Wilk, Dooley and Kessler compared the weather detection capability of the ARSR-1D and WSR-57 near Norman, Oklahoma. However, to our knowledge a comparison of the weather detecting capability of an FAA FPS-67 radar and the WSR-57 has never been made. Since a FAA EPS-67B radar and a WSR-57 were located in Amarillo, Texas within a few miles of each other, we were in a unique position to collect data from both radars simultaneously for comparison.

From March through September 1969, we experimented extensively with a polaroid camera, taking pictures from the Maintenance Scan Converter Scopes. Our pictures improved but still the quality was not comparable to the WSR-57 photos because of the type of equipment involved. However, a cooperative radar data collection program employing PPI scope photography was established by the National Weather Service Southern Region Headquarters in order that we could call the Weather Service Office (WSO) Amarillo, and coordinate the taking of PPI photos. Data collection was generally limited to late afternoon and evening hours due to the new operation and the heavy schedule during the day. The period of data collection was from September 1969 through June 1970. The type of data collected ranged from thunderstorms to light rain and snow.

Before we consider the differences in photos from the WSR-57 and the FPS-67B radars, reference should be made to the following chart which indicates some of the essential differences in characteristics:

COMPARISON OF RADAR CHARACTERISTICS

	WSR-57	FPS-67B
Wave Length	10 cm	23 cm
Peak Power	500 kw	3000 kw
Antenna Gain	39.0 db	35 db
Pulse Length	4 μs	6 μs
Minimum Detectable Signal	-103 dbm	-112 dbm
PRF	164 pps	360 pps
Range	250 nmi	200 nmi
Horizontal Beam Width (half-power points)	2.0°	1.35°
Vertical Beam Width	2.0°	6.2°
Polarization	Linear	Linear and circular

The FAA radars operate at a frequency of 1300 MHz whereas the WSR-57 operates at a frequency of about 2900 MHz. Reflection from a rain drop varies as the fourth power of the frequency. Thus a radar operating at 1300 MHz will receive only 1/16 the power from an echo as one functioning at 2600 MHz, other radar parameters being equal.

While the FAA radars operate at a lower frequency, they do have a much higher power, greater antenna size and better receiver sensitivity so that they have essentially the same weather detecting capability as the WSR-57. As a result they will detect the same amount of rain at the same distance.

The FPS-67B radar has the capability of using circular polarization in either the vertical or horizontal plane and right or left circular polarized. Circular polarization is useful in that the return from a rain drop will be eliminated. The degree of elimination is a function of the degree of ellipticity of the drops and various other factors. As a result, the degree of cancellation will vary from about 8-10 db for snow to about 15-18 db for some rain storms.

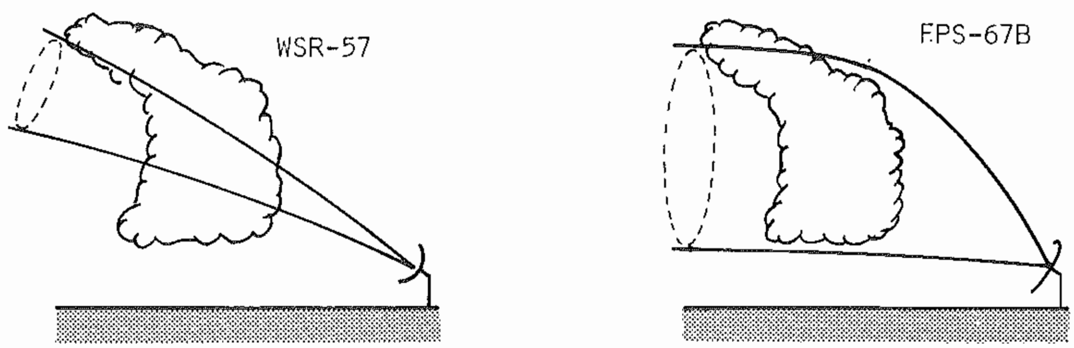
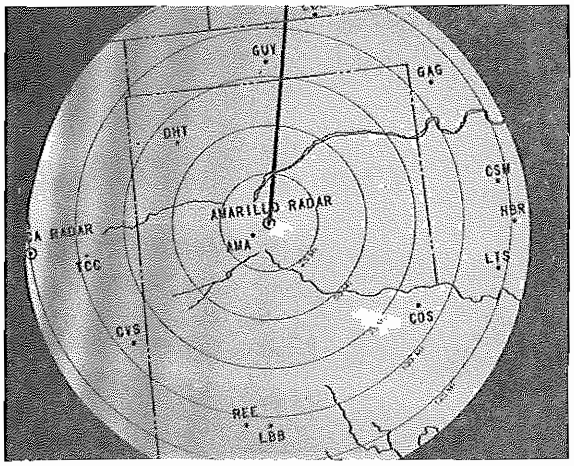


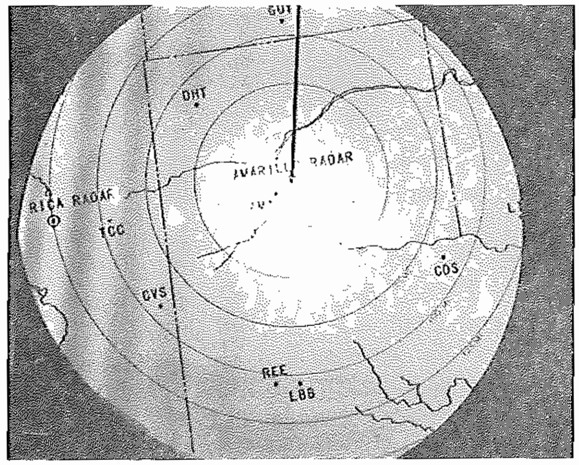
Figure 8

Figure 8 indicates the differences in the vertical of beams of the WSR-57 and the FPS-67B radars. The FPS 67-B has a much wider beam in the vertical and usually detects the entire depth of a storm. This results in a greater depth of precipitation being integrated for scope display.

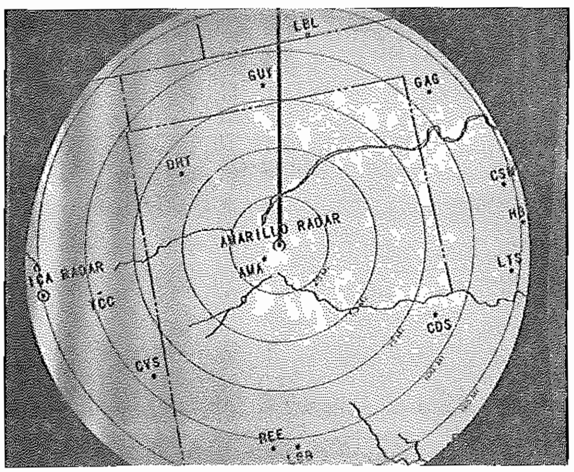
The photos in Figure 9 were taken after midnight, February 9, 1971, when air traffic was nil, in order to show a clear scope devoid of aircraft and weather. In photo 9b this has been accomplished. One should note in this photo the absence of ground clutter around the radar site. In photo 9c the STC was turned off; note the clutter around the center. The STC gate is 60 nautical miles with an attenuation of 7 db. The surface observation at Amarillo, 0800Z, was E37⦶150⊕15 264/28/20/0203/025. Photo 9d has both MTI and STC turned off which renders the PPI scope useless for detecting weather echoes or aircraft out to 50 nmi of the center. In order to work these radars in close, it is necessary to have the suppression circuits.



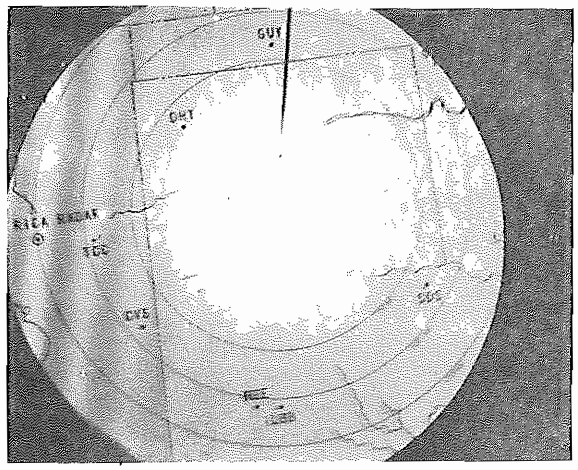
a. MTI and STC <u>on</u> Light snow west and northwest of CDS.



c. MTI <u>on</u> and STC <u>off</u>. Aircraft to the east and north of TCC.



b. MTI and STC <u>on</u>.

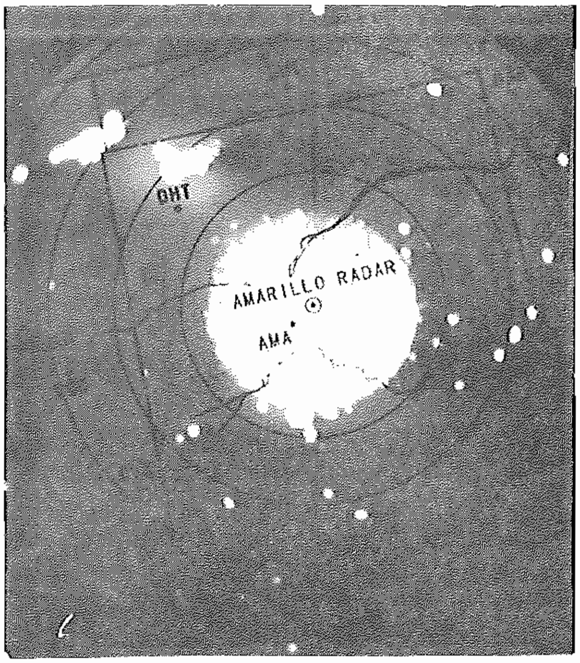


d. MTI and STC <u>off</u>.

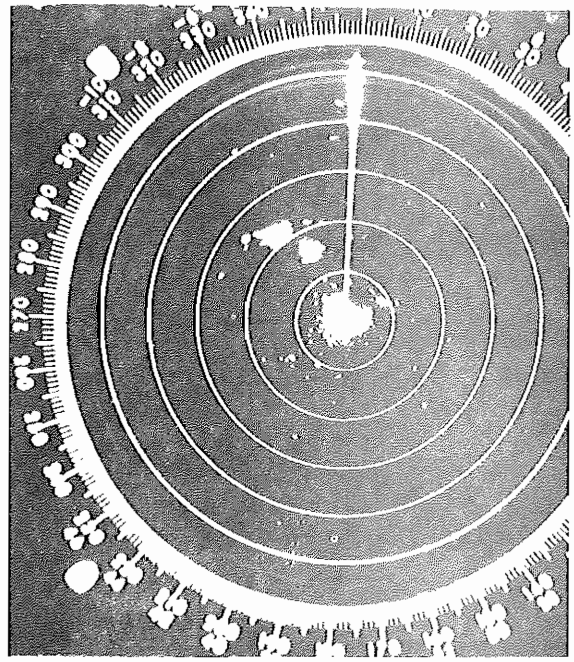
Figure 9. FPS-67B linear polarization with and without MTI and STC cancellation circuits.

Figure 10 shows another situation where the MTI circuitry is inoperative. The MTI gate on the Amarillo FPS-67B radar is 35 nmi. In photo 10a note the bloom around the center out to about 40 nautical miles -- this makes the radar useless for detecting weather or aircraft out to this range. Photo 10b was taken from the WSR-57 at about the same time, showing the thunderstorm activity north and northeast of Dalhart.

In Figure 11 we have a demonstration of the detection capabilities of the FPS-67B radar vs. the WSR-57. The photos show a light rain and snow mixed situation taken at the same time with both radars, with MTI and STC on for the PFS-67B radar. It should be noted that MTI and STC pose no problem in the detection of snow and light rain. The FPS-67B shows more of the snow and light rain. Of interest also is the similarity in the precipitation patterns of the two radars.

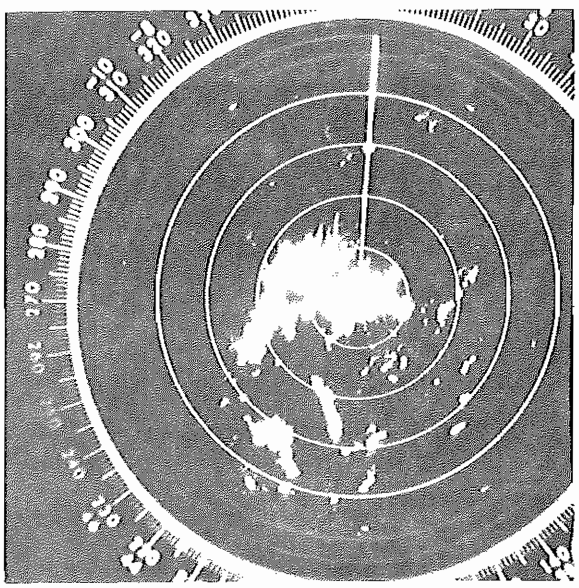


a. FPS-67B...LP on, MTI off, STC on, Range Marks 25nmi.

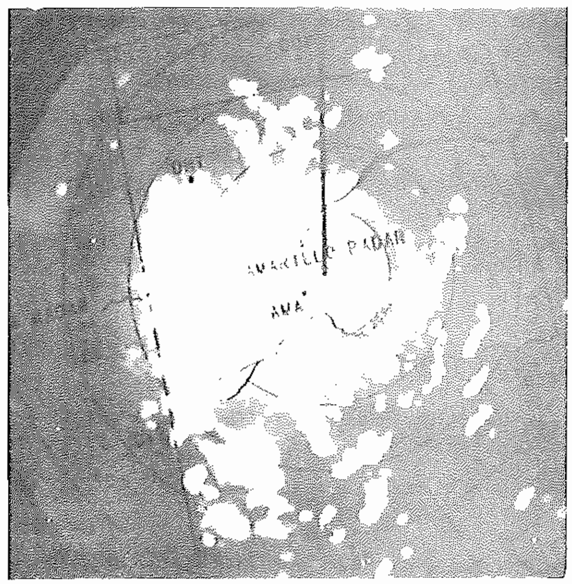


b. WSR-57...Long Pulse, Odb, STC off Range Marks 50nmi.

Figure 10. Thunderstorms Northwest of DHT.



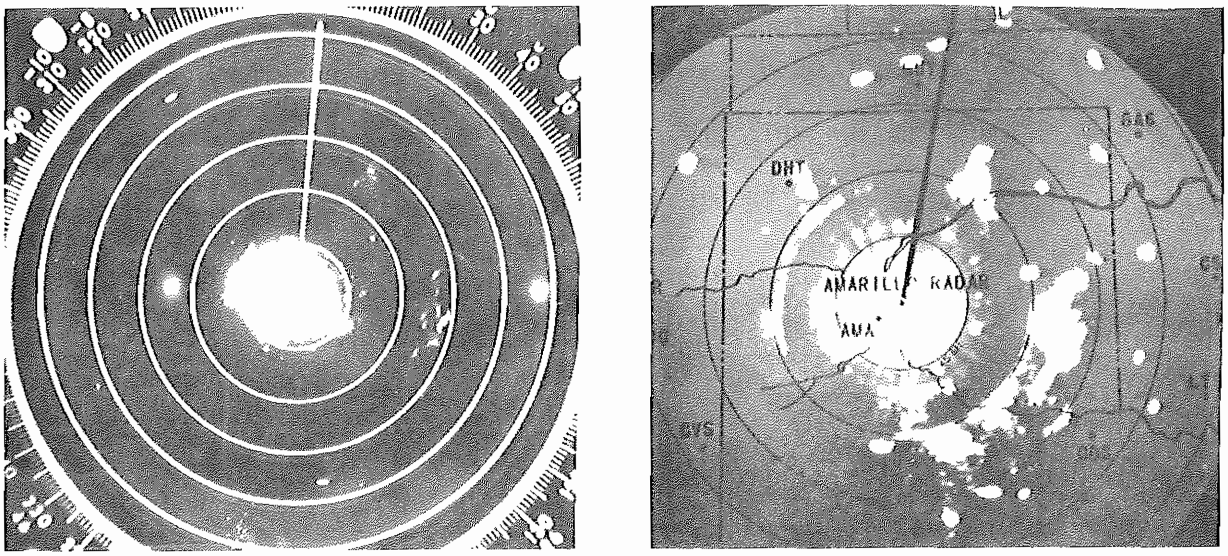
a. WSR-57...STC off, Attenuation Odb, Long pulse. Range Marks 25nmi.



b. FPS-67B...CP off, LP on, MTI on, STC on. Range Marks 25nmi.

Figure 11. Rain and snow mixed at Amarillo, Texas.

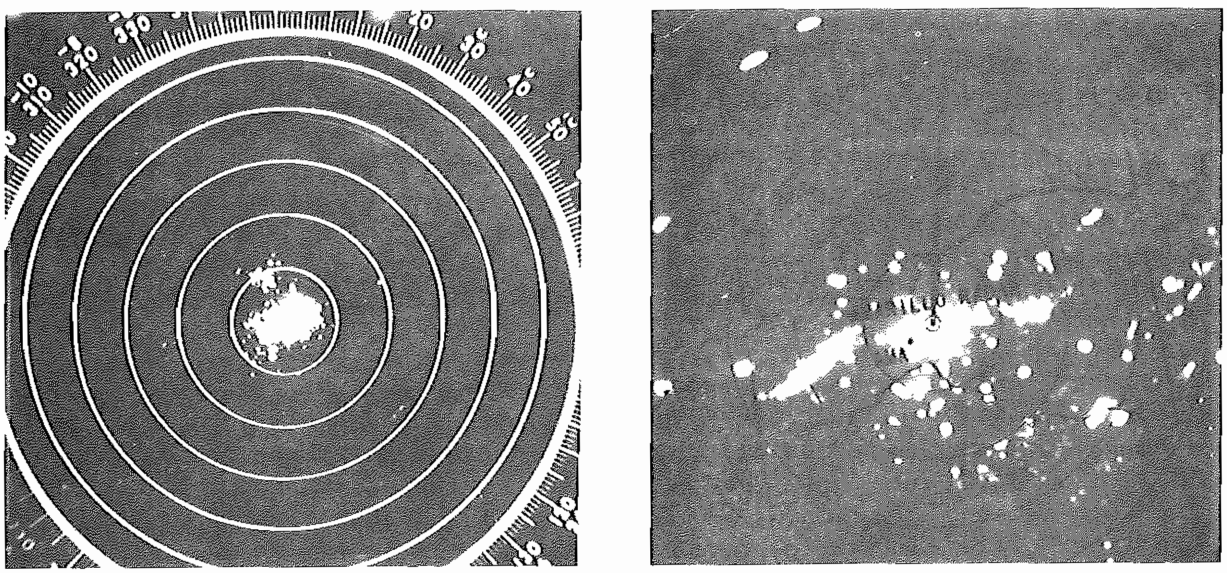
Figure 12 is another example of light snow shown by both radars. The WSR-57B detects a solid area of snow out 30 miles from the center. The FPS-67B radar shows snow out to 30 miles from the center but also indicates bands of snow out to about 75 miles from the center.



a. WSR-57...STC off, Attenuation Odb, Range Marks 25nmi.

b. FPS-67B...LP on, MTI on. STC on. Range Marks 25nmi.

Figure 12. Snow at Amarillo, Texas



a. WSR-57...STC off, Attenuation Odb. Range Marks 25nmi.

b. FPS-67B...LP on, MTI on, STC on. Range Marks 25nmi.

Figure 13. Widespread very light rain and snow at Amarillo.

In Figure 13 we find that the WSR-57 (photo 13a) on standard settings is not detecting the very light precipitation echoes, whereas the FPS-67B radar (photo 13b) indicates a situation of very light rain and snow. This would seem to indicate either that the FPS-67B radar is more sensitive in detecting lighter precipitation or that the WSR-57 was overshooting the precipitation. No doubt the WSR-57 radar would also show some or all of the precipitation if the gain setting were increased, but this procedure would introduce noise into the system which would also show up on the PPI scope. The applicable surface reports and Amarillo RAREPS for this period were as follows:

<u>Surface reports</u> at 2100Z...March 16, 1970

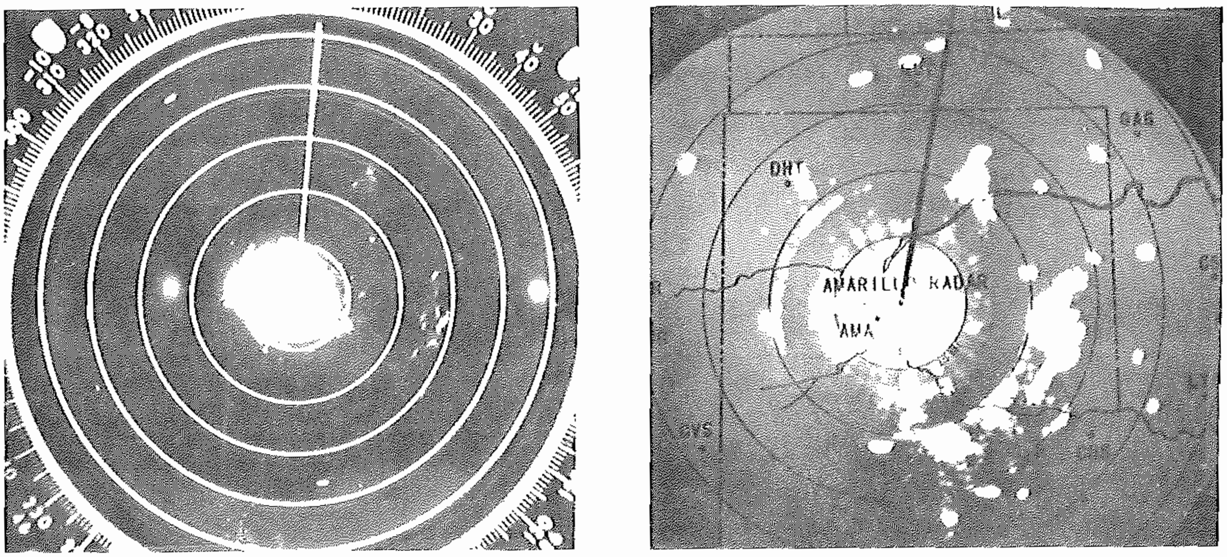
DDC E12⊕4S--F 240/28/26/0511/016
TCC 30⦶U⦶20 193/37/23/0710/006
DHT E10⊕12 209 29 23/0215/009
AMA M7⊕8 183/27/21/0319/002/SE35
CDS B7⊕7R--F 187/34/32/0315/006
GAG S B10⊕8S-- 223/30/25/0314/013
HBR S E5⊕3R--F 187/35/35/0119G24/997
CNM B11⊕4S-- 171/39/36/3515/007
LBB M15⊕12 159/36/28/0415G23/000
ABI M2⊕1½L--F 154/39/36/3416/998/LB09

RAREP AMA WSR-57 PPINE AT 2045Z, 2105Z, and 2145Z.

In Figure 14 we note that for the FPS-67B (17b) the echoes north of Amarillo are well beyond the MTI and STC gates. The echoes appear similar to the echoes on the WSR-57 radar with standard settings. When anti-clutter circuits CP, MTI and STC are not employed, convective weather echo patterns on the ARTC, FPS-67B and WSR=57 radars are very similar to a range of at least 150 nautical miles. In Figure 15 the echoes are also similar with the CP circuit on for the FPS-67B in photo 15b and 18db attenuation for the WSR-57 in photo 15a. In Figure 16 the WSR-57 is attenuated 24db. This picture does not quite compare with photo 15. Therefore we could conclude that the CP on the FPS-67B radar is approximately 18db attenuation on the standard WSR-57. The Amarillo WSR-57 RAREP for June 2, 1970 at 0045Z was as follows:
AMA AREA⦶TRW-/NEW 326/107 28/68 320/35 MAX TOP 210 AT 7/63.

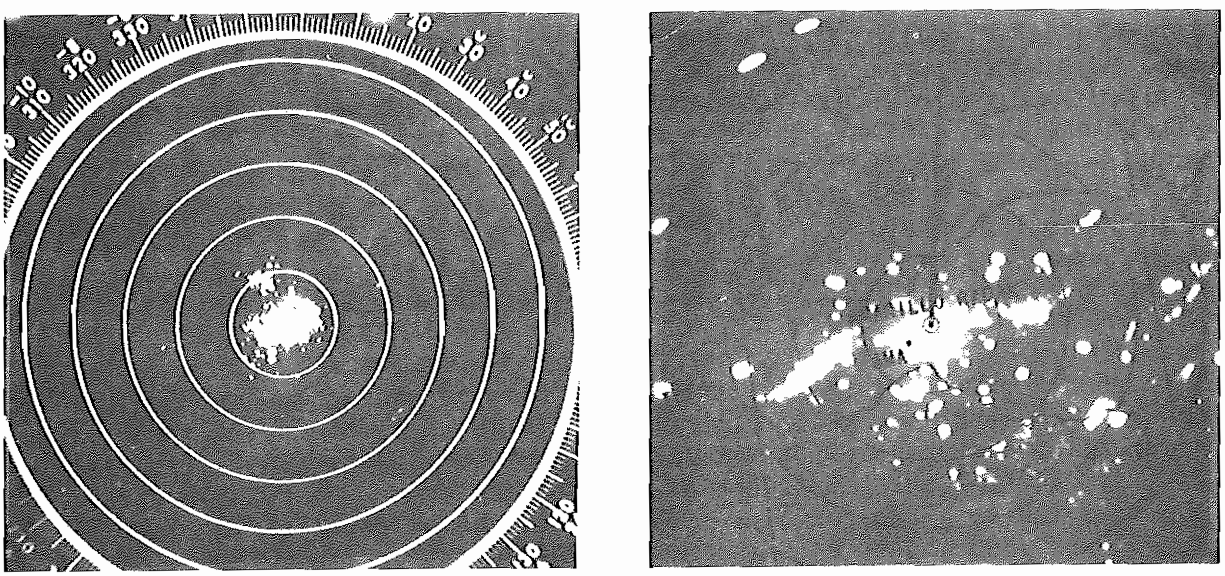
A thunderstorm situation is indicated on both radars in the photos in Figure 17. In this case the photos are similar. In photo 17a the attenuation for the WSR-57 is 0db, and in photo 17b the FPS-67B is also free of attenuation. The bloom around the center on the FPS-67B was due to a faulty STC circuit. In Figure 18a the attenuation for the WSR-57 was 12db and in Figure 18b the FPS-67B was in the CP mode. These photos seem to indicate that the CP for the FPS-67B allows for more attenuation than the 12db for the WSR-57. In Figure 19 the attenuation for the WSR-57 is 24db, but this seems to be more attenuation than that with the CP on for the FPS-67B in photo 18b. This demonstrates that the CP attenuation is more than 12db but less than 24db. This again suggests the approximation of CP at about 18db.

Figure 12 is another example of light snow shown by both radars. The WSR-57B detects a solid area of snow out 30 miles from the center. The FPS-67B radar shows snow out to 30 miles from the center but also indicates bands of snow out to about 75 miles from the center.



a. WSR-57...STC off, Attenuation Odb, Range Marks 25nmi.
b. FPS-67B...LP on, MTI on. STC on. Range Marks 25nmi.

Figure 12. Snow at Amarillo, Texas



a. WSR-57...STC off, Attenuation Odb.
b. FPS-67B...LP on, MTI on, STC on. Range Marks 25nmi.
Range Marks 25nmi.

Figure 13. Widespread very light rain and snow at Amarillo.

In Figure 13 we find that the WSR-57 (photo 13a)on standard settings is not detecting the very light precipitation echoes, whereas the FPS-67B radar (photo 13b) indicates a situation of very light rain and snow. This would seem to indicate either that the FPS-67B radar is more sensitive in detecting lighter precipitation or that the WSR-57 was overshooting the precipitation. No doubt the WSR-57 radar would also show some or all of the precipitation if the gain setting were increased, but this procedure would introduce noise into the system which would also show up on the PPI scope. The applicable surface reports and Amarillo RAREPS for this period were as follows:

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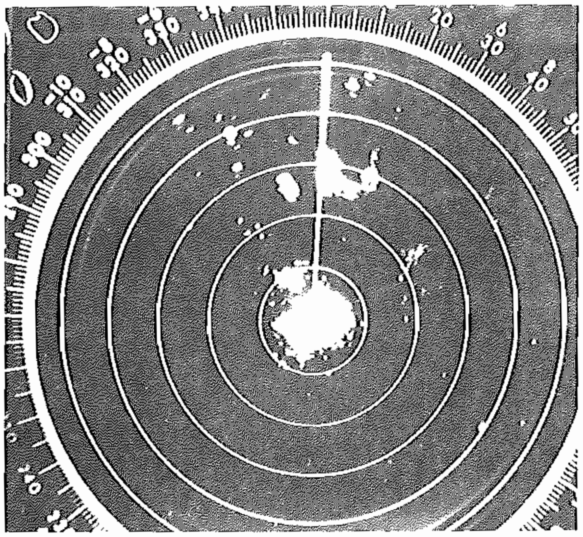
DDC E12⊕4S--F 240/28/26/0511/016
TCC 30ⓄU⊕20 193/37/23/0710/006
DHT E10⊕12 209 29 23/0215/009
AMA M7⊕8 183/27/21/0319/002/SE35
CDS B7⊕7R--F 187/34/32/0315/006
GAG S B10⊕8S-- 223/30/25/0314/013
HBR S E5⊕3R--F 187/35/35/0119G24/997
CNM B11⊕4S-- 171/39/36/3515/007
LBB M15⊕12 159/36/28/0415G23/000
ABI M2⊕1½L--F 154/39/36/3416/998/LB09

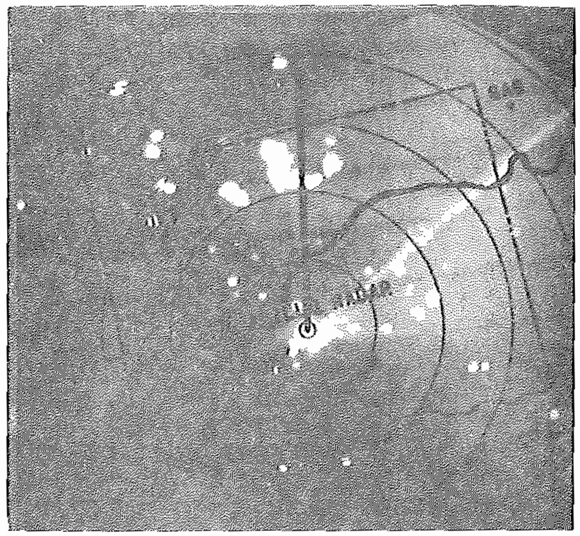
RAREP AMA WSR-57 PPINE AT 2045Z, 2105Z, and 2145Z.

In Figure 14 we note that for the FPS-67B (17b) the echoes north of Amarillo are well beyond the MTI and STC gates. The echoes appear similar to the echoes on the WSR-57 radar with standard settings. When anti-clutter circuits CP, MTI and STC are not employed, convective weather echo patterns on the ARTC, FPS-67B and WSR=57 radars are very similar to a range of at least 150 nautical miles. In Figure 15 the echoes are also similar with the CP circuit on for the FPS-67B in photo 15b and 18db attenuation for the WSR-57 in photo 15a. In Figure 16 the WSR-57 is attenuated 24db. This picture does not quite compare with photo 15. Therefore we could conclude that the CP on the FPS-67B radar is approximately 18db attenuation on the standard WSR-57. The Amarillo WSR-57 RAREP for June 2, 1970 at 0045Z was as follows:
AMA AREAⓄTRW-/NEW 326/107 28/68 320/35 MAX TOP 210 AT 7/63.

A thunderstorm situation is indicated on both radars in the photos in Figure 17. In this case the photos are similar. In photo 17a the attenuation for the WSR-57 is 0db, and in photo 17b the FPS-67B is also free of attenuation. The bloom around the center on the FPS-67B was due to a faulty STC circuit. In Figure 18a the attenuation for the WSR-57 was 12db and in Figure 18b the FPS-67B was in the CP mode. These photos seem to indicate that the CP for the FPS-67B allows for more attenuation than the 12db for the WSR-57. In Figure 19 the attenuation for the WSR-57 is 24db, but this seems to be more attenuation than that with the CP on for the FPS-67B in photo 18b. This demonstrates that the CP attenuation is more than 12db but less than 24db. This again suggests the approximation of CP at about 18db.

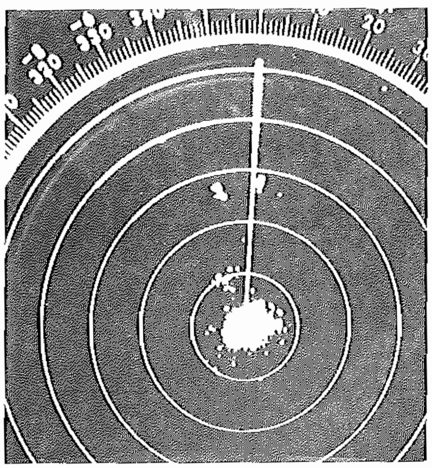


a. WSR-57...STC off,
Range Marks 25nmi.



b. FPS-67B...LP on, MTI on, STC on.
Range Marks 25nmi.

Figure 14. Thundershowers forming north of Amarillo.



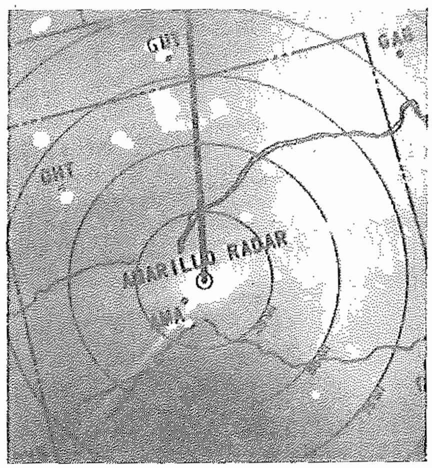
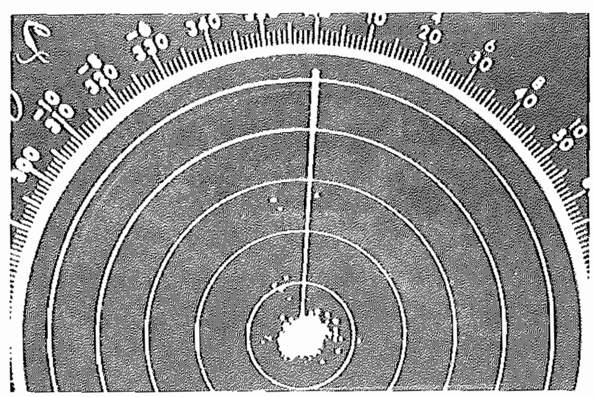


Figure 15.(left) Thundershowers north of Amarillo.

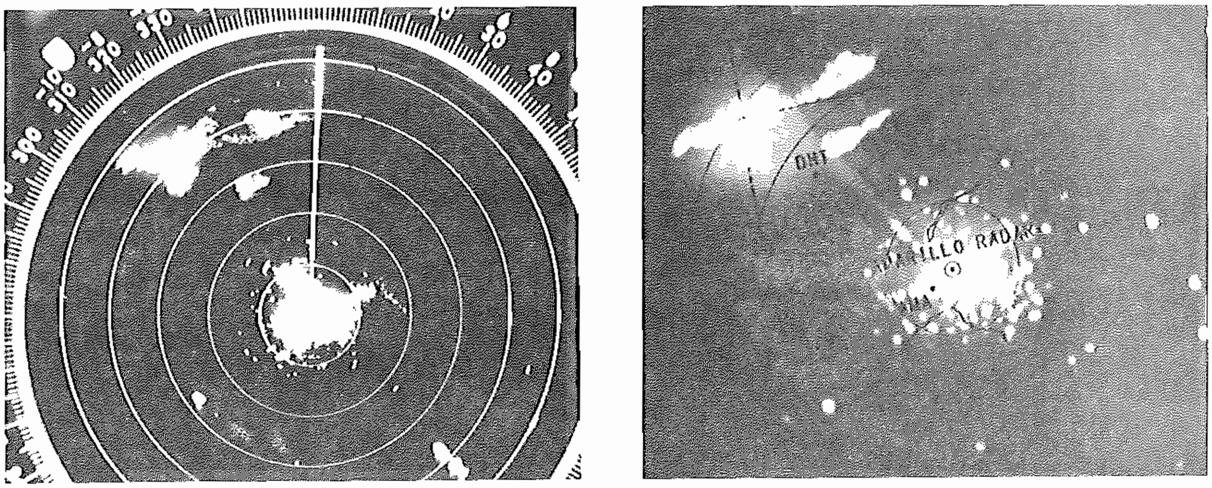
a. WSR-57...STC off, 18db Long Pulse,
Range Marks 25nmi.

b. FPS-67B...CP on, MTI on, STC on
Range Marks 25nmi.

Figure 16. (right) Thundershowers north of Amarillo. WSR-57 24db.
STC off, Long Pulse.
Range Marks 25nmi.



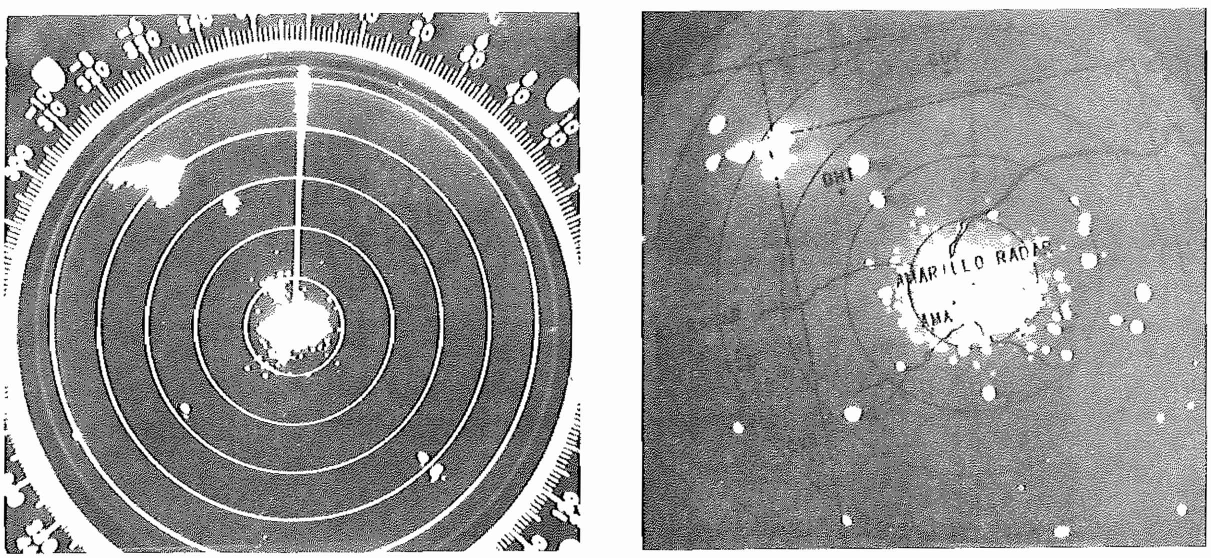
A thunderstorm situation is indicated on both radars in the photos in Figure 17. In this case the photos are similar. In photo 17a the attenuation for thw WSR-57 is 0db, and in photo 17b the FPS-67B is also free of attenuation. The bloom around the center on the FPS-67B was due to a faulty STC circuit. In figure 18 the photos seem to indicate that the CP for the FPS-67B allows for more attenuation than the 12db for the WSR-57.



a. WSR-57...STC off, 0db, Long Pulse. Range Marks 25nmi.

b. FPS-67B...LP on, MTI on, STC on. Range Marks 25nmi.

Figure 17. Thunderstorms in vicinity of Dalhart.



a. WSR-57...STC off, 12db, Long Pulse. Range Marks 25nmi.

b. FPS-67B...CP on, LP off, MTI on, STC on. Range Marks 25nmi.

Figure 18. Further comparisons for meteorological situation of Fig. 17.

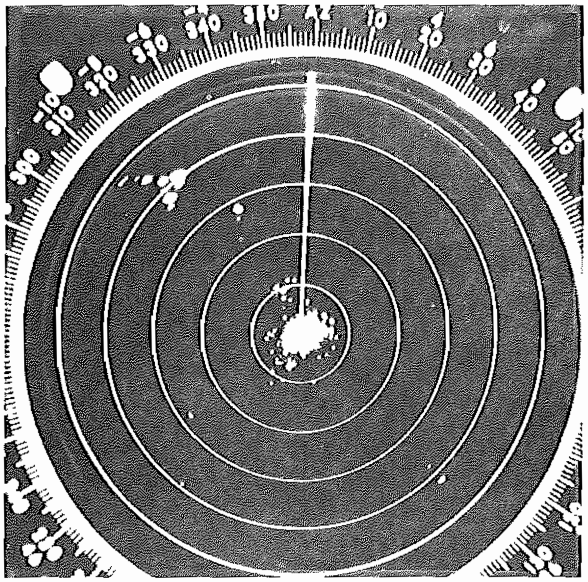


Figure 19. Meteorological Situation of Figures 17 and 18; WSR-57...STC off, 24db, Long Pulse, Range Marks 25nmi.

In Figure 19 the attenuation for the WSR-57 is 24db, but this seems to be more attenuation than that with the CP on for the FPS-67B in photo 18b. This demonstrates that the CP attenuation is more than 12db but less than 24db, again suggesting the approximation of CP at about 18db.

Figure 20 (ABQ-ARTC Radar Collective Chart), below, takes into account the CP attenuation in calling the thunderstorms strong. Surface reports and RAREPS for the times closest to the photos above follow:

Surface Reports at 0000Z...September 17, 1969

DHT	70⦶/⦶15+	134/74/56/1010/005/ CB NE
AMA	40⦶15+	117/79/55/1111/000
LBB	O15	121/77/61/0708/XXX/ CB DSNT NW
CVS	E50⦶/⦶15	114/79/53/1108/004/ CB N AND ENE MOVG SSE
TCC	40⦶30	115/80/53/0000/001/ CB TCU NW-N

SD 162345Z
AMA AREA⦶TRW+/NC 356/111 335/69 307/133 3110 MAX TOP 330 AT 331/75 MOSTLY TRW
AREA⦶TRW-/+ 233/68 D10 0000 TOP 220
CELL TRWU/NEW 355/183 D8

SD 170045Z
AMA LN⦶TRW/NC 355/85 307/110 30W 3215 MAX TOP 360 AT 318/89
CELL RW-/NC 230/68 D6 0000 TOP 180

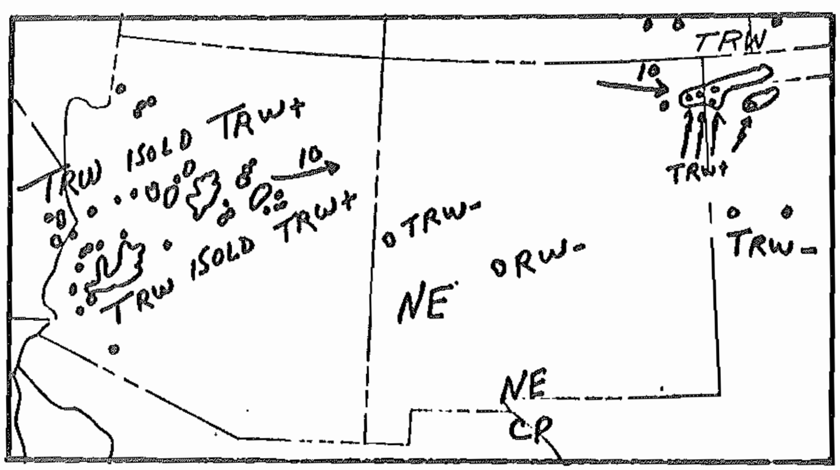
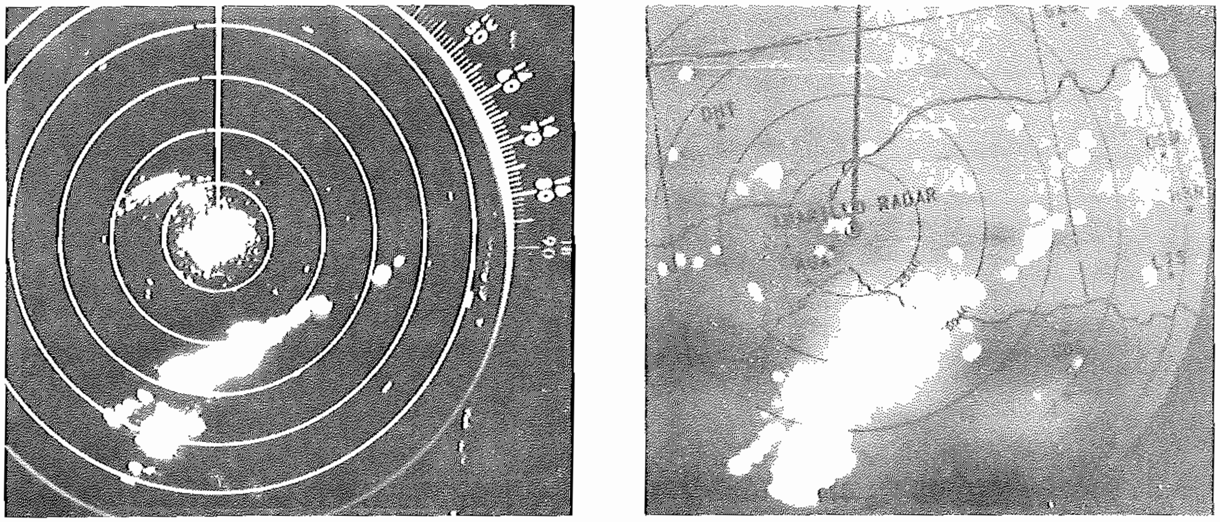


Figure 20.(Right) ABQ-ARTC Radar Collective Chart.

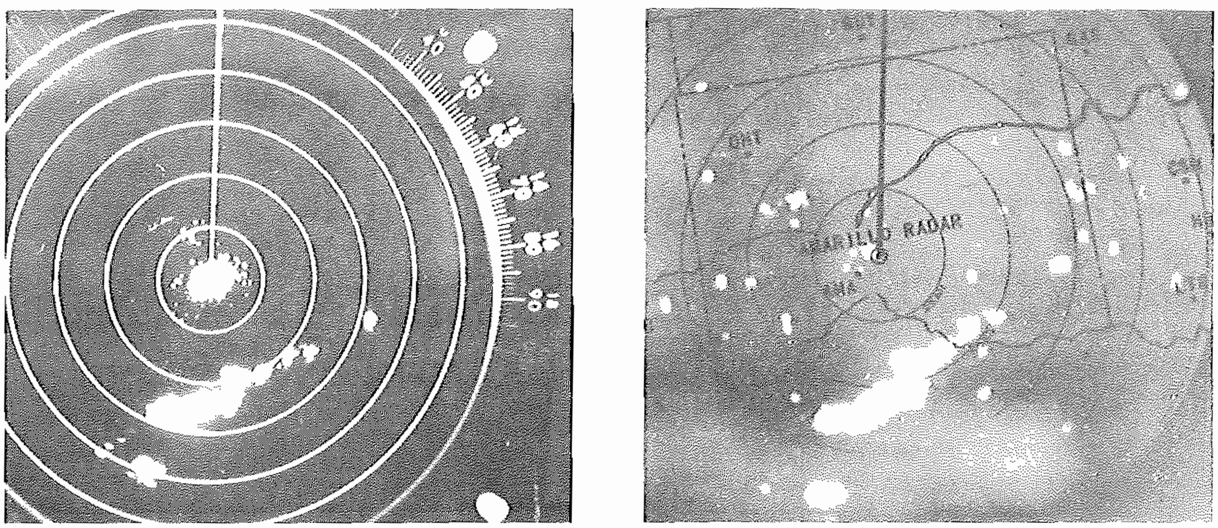
Beginning with Figure 21 we have indications of a solid line of heavy thunderstorm activity. Photos 21a and 21b are similar, with no attenuation for either radar. In photo 22a attenuation of 18db has been added to the WSR-57, and in photo 22b the CP mode was on for the FPS-67B. Note the similarity of the two photos, indicating again that the CP mode is approximately 18db.



a. WSR-57...STC off, 0db, Long Pulse, Range Marks 25nmi.

b. FPS-67B...LP on, MTI on, STC on. Range Marks 25nmi.

Figure 21. A line of thunderstorms.



a. WSR-57...STC off, 18db, Long Pulse, Range Marks 25nmi.

b. FPS-67-B...CP on, MTI on, STC on, Range Marks 25nmi.

Figure 22. Same situation as Fig. 21

Figure 23 shows that the line of thunderstorms had increased in length and coverage during the next hour. Numerous tornadoes were reported in the western portion of this line. A 500mb low was located in west central Texas, and the thunderstorms formed rapidly during the afternoon along an active cold front. The western portion of the line was moving northwestward, and the eastern portion was moving southeastward. The following Amarillo RAREPS for 2145 and 2245Z were received:

```
SD 142145Z
AMA SPL  LN⌽TRW+/NC  142/51  196/83  202/131  15W  0000  MAX
         TOP  400  AT  162/53  400  AT  196/93  HAIL INDCD AT
         2130 TORNADO RPTD SW SILVERTON
         CELL  TRWU/NEW  72/150  D18

SD 142245Z
AMA SPL  AREA⌽TRW+/NC  88/117  209/108  10W  N END  40W S END
         0000  CELLS 0000  MAX TOP 450 AT 202/70  500 AT 182/66
         INCLS SOLID
         LN FROM 120/63  TO 202/76  WITH NUMEROUS TORNADOES RPTD
         IN THIS LINE
         CELLS TRWU/NEW  279/178  285/77 D8
```

Summary: This study has attempted to compare the WSR-57 and FPS-67B radars in regard to their capabilities in weather detection. The basic characteristics of both radars have been indicated. The FPS-67B operates at a lower frequency than the WSR-57, but has a much higher power, greater antenna size and better receiver sensitivity, which offset its lower frequency. It was indicated that the vertical beam widths of the radars are different, the FPS-67B having a larger beam in the vertical. However, the beams are similar for the two radars in the horizontal.

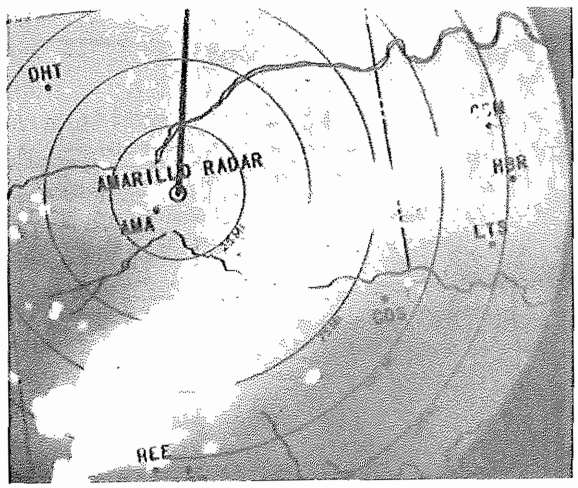


Figure 23. A Solid Line of Strong Thunderstorms as seen on FPS-67B. LP on, MTI on, STC on. Range Marks 25nmi.

Numerous photos of light rain, snow, and heavy thunderstorms were used for comparative purposes. One of the conclusions was that the CP mode on the FPS-67B in the on position was equivalent to 18db on the standard WSR-57. When the anti-clutter circuits CP, MTI, and STC were not employed, convective weather echo patterns on the ARTC, FPS-67B and the WSR-57 radars are very similar to a range of at least 150 nautical miles. The photos also seem to indicate that the FPS-67B shows more of the lighter precipitation in the form of light snow and rain and at a greater distance.

IV. GENERAL WEATHER DETECTION CAPABILITIES OF THE FAA RADARS.

Weather detection capabilities of FAA radars as compared to the WSR-57 have been discussed in depth in the previous section. Under section V, Applied Studies, a demonstration of FAA Radar vs Ground reports will be presented. Therefore, this section will be generally devoted to specific examples of detection to show that, although not designed for weather detection, FAA radars do the job quite nicely.

A. TORNADO OCCURRENCE NEAR EL PASO, TEXAS ON 2 JUNE 1969.

During the early afternoon on June 2, thunderstorms began to develop rather rapidly in Mexico near El Paso and Hudspeth Counties. This activity was recorded on the composite radar overlay prepared at 1818Z. This echo activity (Figure 24) increased in intensity while drifting northward toward the El Paso area. By 2000Z, a large, strong cell was observed south of the city, and at about the same time an FAA controller called to report that a pilot had just observed a funnel cloud extending from the cloud associated with the strong cell. Within a few minutes of the first report, another pilot reported seeing a funnel in the same area,

Now on the alert for possible tornadoes, radar weather specialists closely studied the strong cell, and at approximately 2010Z found an appendage on the south side of the large intense echo. A photograph (Figure 25) was taken at this time. Figure 26 shows the geographic location of the strong cell and accompanying shower activity. Based on these indications, the El Paso WSO was advised of the possibility of severe weather in their counties of responsibility. Consequently, the WSO issued a tornado warning at 1445 MDT, ending at 1545 MDT, and severe thunderstorm warning extending to 1615 MDT.

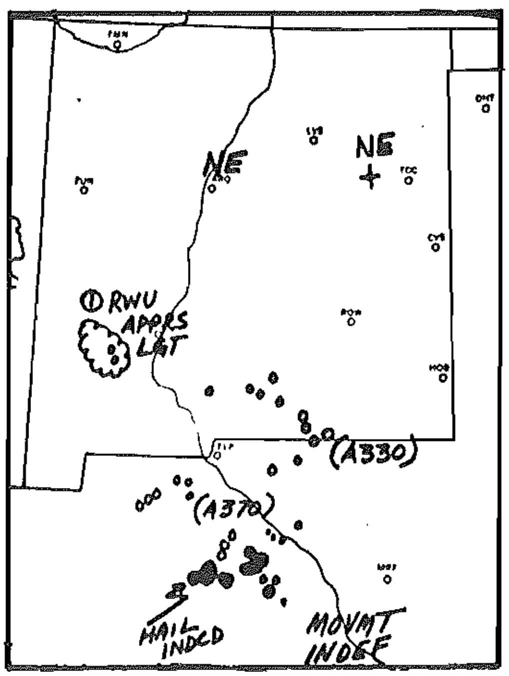


Figure 24. Overlay at 1818Z

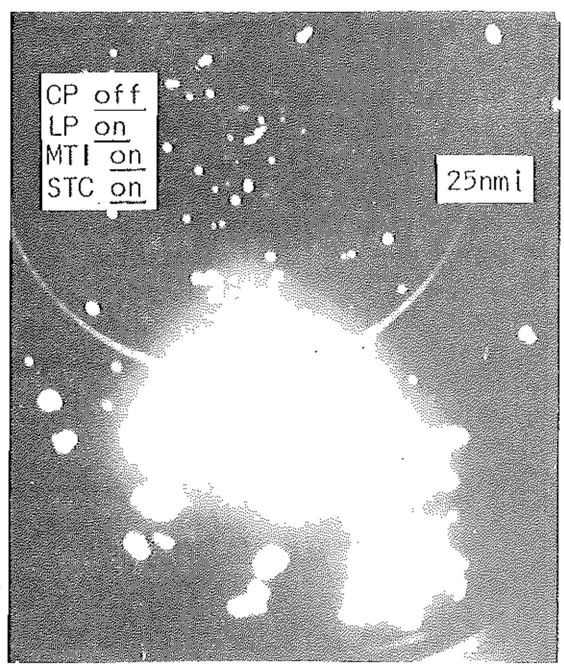


Figure 25. 2010Z Hook Echo on ASR-IE

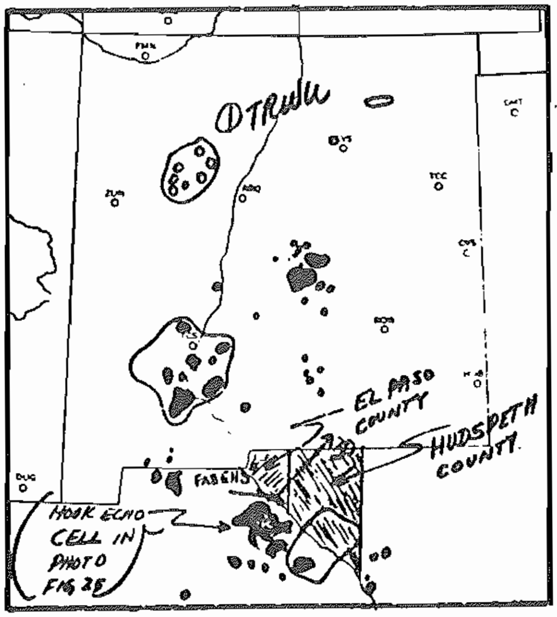


Figure 26.

Shortly after the warnings were issued, reports of high winds, large hail, heavy rain, and some property damage in El Paso County were received from the Bureau of Reclamation and the El Paso Electric Company. No casualties or tornadoes were reported; however, a tornado could have occurred without being reported since the area south of El Paso is sparsely settled.

B. HURRICANE CELIA, AUGUST 1970

The El Paso ARTCC radar first picked up a north-south aligned band in the northwest quadrant of the storm approximately over the Hueco Mountain ridge east of El Paso late in the day on August 4th. A discernible echo

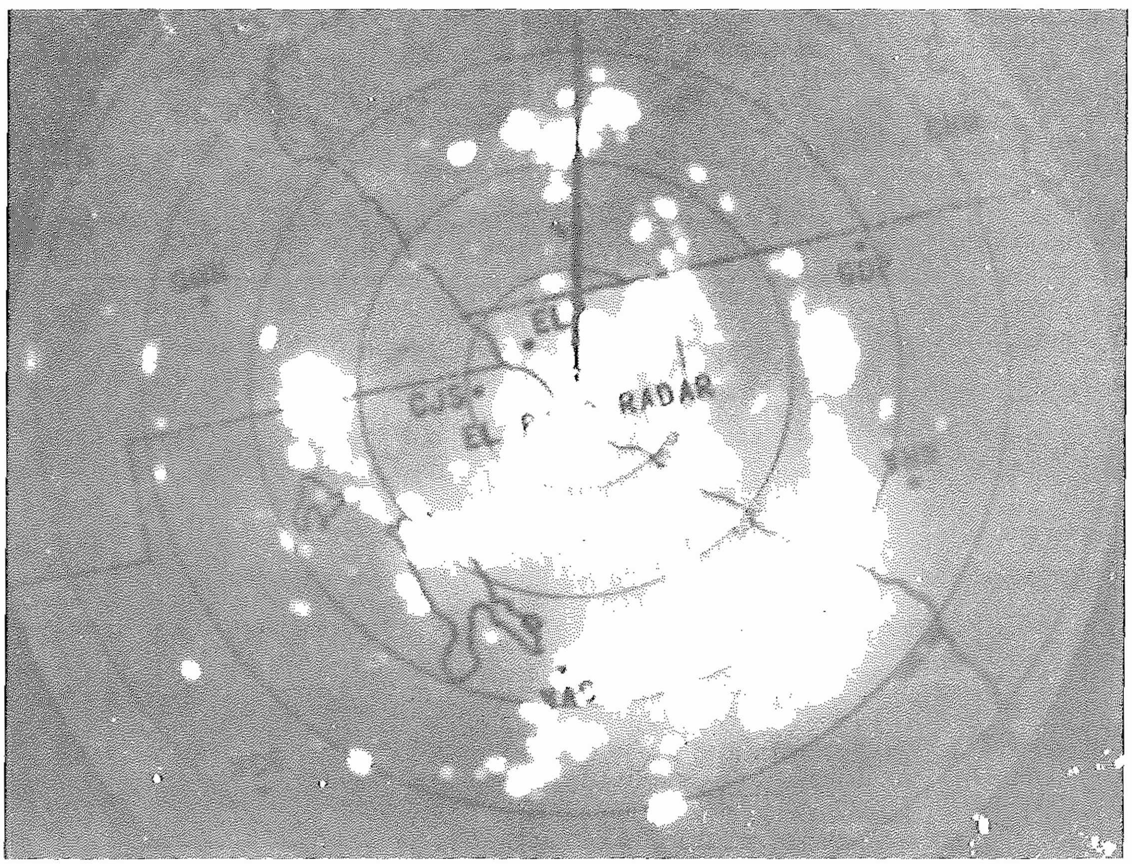


Figure 27. Typical Spiral Banding Indicated on El Paso Radar.

pattern defining a center was first visible from the El Paso radar at 0125Z on August 5th and was located near Van Horn, Texas. By 0425Z the spiral banded circulation was clearly evident on this radar and remained so through the 1625Z observation by which time it was located a few miles east of Deming, New Mexico.

C. FINE LINE DETECTION

Fine lines seem to be best seen at long ranges with powerful, sensitive radars. In this regard, ARTC radars are particularly useful for investigating fine-lines. Although many have been observed, few, if any, have persisted as long as the one observed on 14 September 1971. First detected near the Oklahoma-Texas Panhandle border at 1430Z, the fine-line echo associated with the dry, cloudless cold front was monitored by the Albuquerque complex of ARTC radars for nine hours (Figure 28). The front moved southward at an average speed of about 12 mph and slowed after passing Amarillo to become quasi-stationary in the vicinity of a Clovis-Allison, Texas line at about 2100Z. The fine-line persisted until 2325Z.

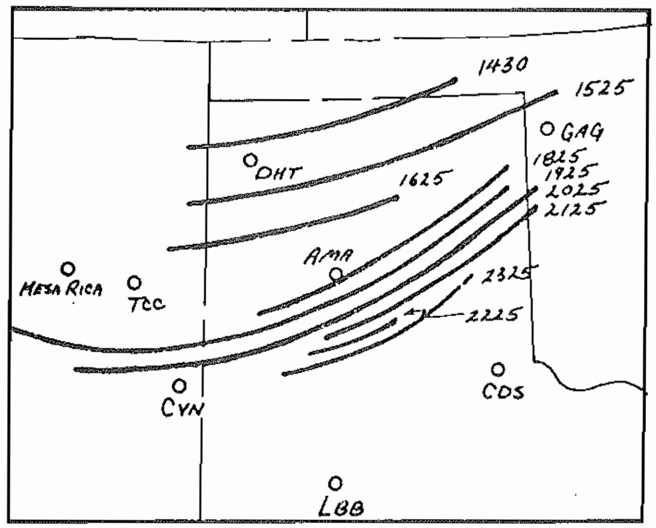


Figure 28. Fine-line

Pictured in Figure 29 is a fine-line detected on the Amarillo ARTCC radar. Interesting to note is the fact that the echo at the time practically intersects the radar site and is well defined with both MTI and STC on.

D. CHAFF

Chaff, usually released as several parallel bands, spreads as it falls and is readily detected on ARTC radar as evidenced by the photo in figure 30. The photo was taken from the display on the Amarillo Scan converter.

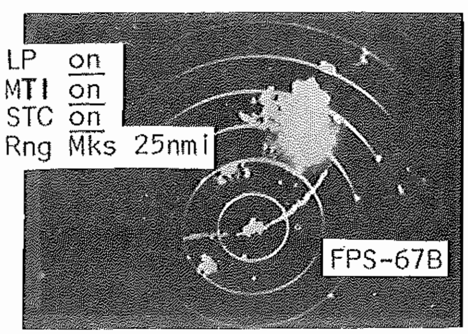


Figure 29. Fine-line and dissipating thundershowers

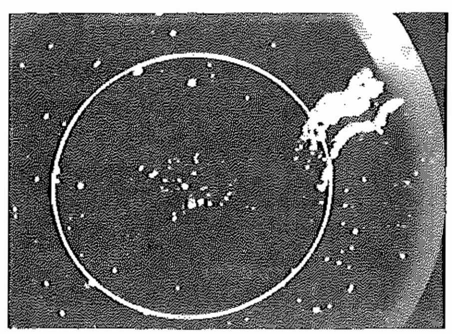


Figure 30. Chaff. Radar characteristics same as figure 29.

E. RAIN AND SNOW. Rain and snow, particularly during the winter months, when compared to convective type activity, is the most difficult to detect. This is not peculiar to the ARTC radars but applies to the WSR-57 as well. Although some low level precipitation goes undetected, the ARTC radars compare favorably with the WSR-57,as is born out in the comparative study contained in Section III. The difficulty in detection of precipitation targets of this type is due particularly to the broad vertical beam width of the ARTC radars which presents a beam cross section that is seldom filled by light rain or snow, especially at the longer ranges. In addition, FAA radar transmitters are located on high terrain with the antenna tilted upward about 2 degrees, causing the radar beam to overshoot low-level precipitation.

Figure 31 shows the presentation of the West Mesa (ABQ) radar when snow was falling over eastern Arizona and the western and northern portions of New Mexico while to the southwest, rain and snow mixed was being experienced. It suggests that for snow or rain from stratiform clouds, 85nmi may be the approximate range limit for detection.

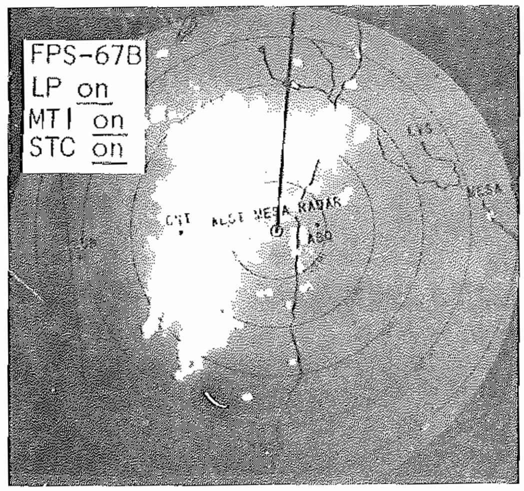


Figure 31. Rain and snow mixed(SW), Snow (W-N).

F. THUNDERSTORMS. The capability of ARTC radars to detect thunderstorms is discussed at length in other sections of this paper. Therefore, let it suffice here to say that this phenomenon rarely goes undetected. Figures 32 through 35 show the typical appearance of strong thunderstorms.

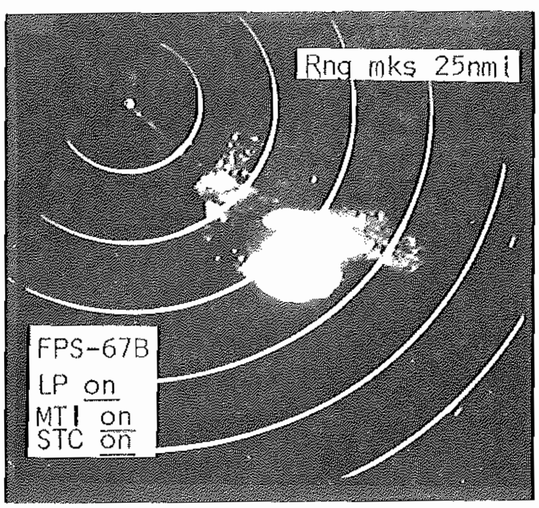


Figure 32. Strong Thunderstorm

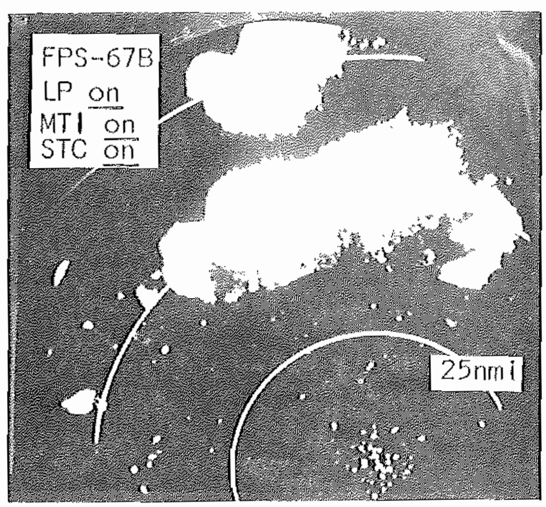


Figure 33. Strong Thunderstorm Activity; Little Attenuation Noted-Strong Cell Detected to Rear of Line.

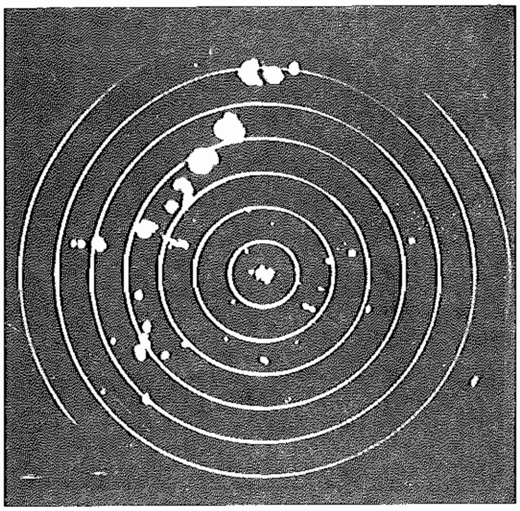


Figure 34. Line of Thunderstorms. Same radar characteristics as fig.33.

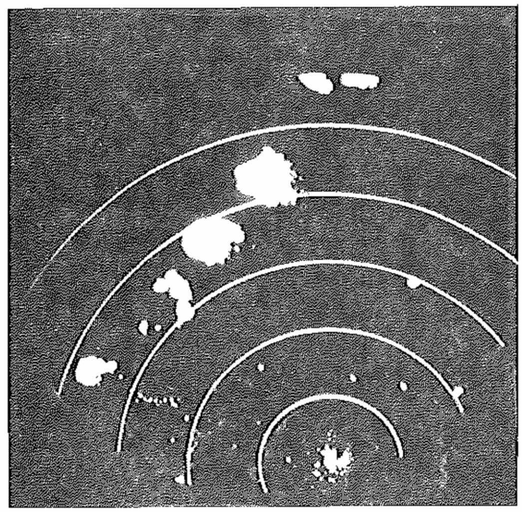


Figure 35. Thunderstorms; Tops 55,000 ft., Hail indicated. Radar characteristics same as 33.

V. APPLIED STUDIES

A. THUNDERSTORM DETECTION BY ALBUQUERQUE ARTC. RADARS. The first study involving Albuquerque ARTC radars was completed by Wendell Logan in 1970. It discussed the implications of design characteristics, suppression circuits and terrain blocking, and the importance of utilizing the complex as a single unit due to interlocking and overlapping coverage. Also included was a comparison of radar vs. ground reports. Following is part of the report with portions such as characteristics of ARTC radars deleted since they appear elsewhere in this paper:

1. Enhancement of detection due to interlocking, overlapping coverages. It is true that when one ARTC radar is compared with a standard Weather Service radar (WSR-57) it appears far less effective. However, when the six radars in the complex are considered as a single unit they compare quite favorably. Design and suppression circuits become far less significant, and terrain blocking much less of a detriment in the detection of weather targets for the following reasons. The use of circular polarization remains entirely with the aircraft controller. However, it takes only about one minute to switch the radar from one mode of polarization to the other. Controllers at this facility are aware of the value of weather intelligence and are most cooperative in effecting mode changes upon request, whenever possible. When considering the complex as a single unit, CP can be used to advantage. All systems in the complex overlap in coverage as indicated in figure I. During the thunderstorm season, for example, numerous strong cells and lines develop in eastern New Mexico. Since the radars at Mesa Rica near Tucumcari and at Amarillo entirely overlap the area between the two cities, it is advantageous to have one radar on LP and the other on CP. In this way one radarscope displays weather unsuppressed by the circuit while the other displays the same weather targets with an attenuated return signal of 12 or 21 db depending upon whether or not the echo is within the MTI gate.

Worthy of mention is the fact that when users see that a system is on CP mode, this does not necessarily mean that the particular radar is less effective than the one in LP mode. It often means that two adjacent radars, each in a different mode, are being used in conjunction for the purpose of detecting the strongest portion of the target.

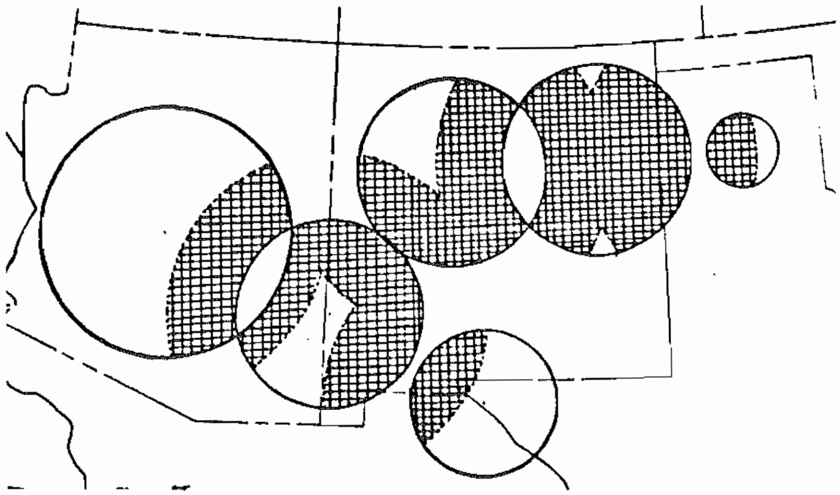


Figure 36. Overlapping of MTI Gates

MTI and STC anti-clutter circuits, as previously mentioned, are designed to degrade weather targets. However, it is very important for the operator and user to consider the complex as a single unit. Considerable overlapping of coverage by the radars within the complex does exist. Figure 36 illustrates that overlapping of adjacent radars offers considerable coverage outside their own gate and within the MTI gate and STC suppression area of another radar while still within the effective range of 150 miles. Wherever this overlap occurs the detection of weather targets is effected as though MTI or STC were not employed. Further, signal suppression by use of STC circuits is applied in areas where ground clutter is a factor and in mountainous country such as New Mexico and Arizona, these circuits, although theoretically undesirable, are absolutely necessary. Although the signal is suppressed to a point whereby weather targets are very difficult to detect within 30 miles of the radar site, it would be as difficult, or more difficult, to pick weather targets out of ground clutter without its use.

The significance of terrain blocking, when several overlapping radars are employed, is reduced considerably and may, at times, be used to advantage. The proper control of aircraft dictates that they must be seen at all times, therefore the choice of ARTC sites within a complex depends greatly upon the terrain.

Here again, the utilization of the complex as a single unit is very important. A weather target over Las Vegas, New Mexico, which is located on the eastern slopes of the Sangre de Cristo range with peaks above 10,000 feet in height is required to be at least 29,000 feet high to be detected by the West Mesa site near Albuquerque. However, this target need only be 10,000 feet high to be detected by the radar located at Mesa Rica near Tucumcari. It is essential that more than one radar come into focus when determining minimum detectable heights of weather targets over any specific point. Here again, the blocking can be used to some advantage. If an echo is detected over Las Vegas on the West Mesa radarscope it has to have a top of at least 29,000 feet while on the other hand, if it can not be seen on this scope but is displayed on the Mesa Rica scope its top is between 10 and 29 thousand feet. Growth rate estimates, for example, can be made by comparing the time indicated on one scope to the time indicated on another.

Considering all radars, the minimum detectable height is reduced considerably as shown in Figure 37. For security reasons, only Phoenix, Silver City, and El Paso radars are used for illustration.

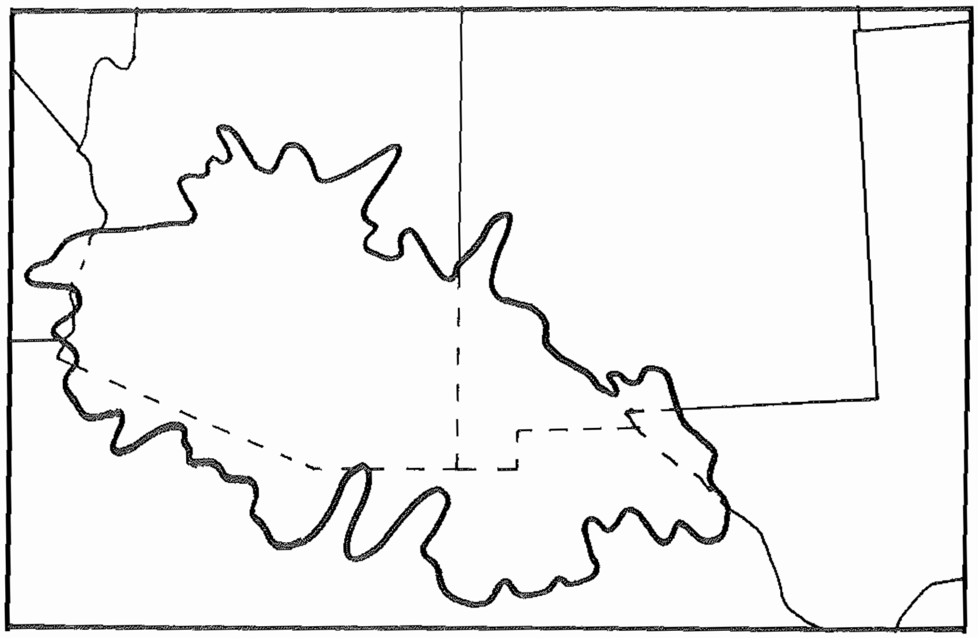


Figure 37. Area outside of which targets will not be detected by El Paso, Phoenix, or Silver City radars unless tops exceed 10,000 feet.

2. Comparison of radar vs ground reports. To demonstrate the capability of the six radars to detect thunderstorms when utilized as a single unit, data were collected from nineteen selected stations. All stations were within the effective range of 150nmi. Thunderstorms reported in aviation observations during the period 1 August 1969 to 31 October 1969 were tabulated. No attempt was made to determine cause or by which radarscope the weather target was detected and a target displayed within ten nautical miles of the reported occurrence was considered verification. Figure 38 shows the percentage of the reported thunderstorms detected by radar and (in parentheses) the actual number reported. Analysis of the data collected clearly indicates that thunderstorms are detected by the six Albuquerque radars regardless of the mode of polarization (CP or LP), terrain blocking, MTI or STC. During the three month period covered by the study, 274 thunderstorms occurred at the 19 stations selected during the limited times when radar personnel were on duty. Of the 274 thunderstorms reported, 249, or 91% were detected on radarscopes and transmitted to the users. Stations

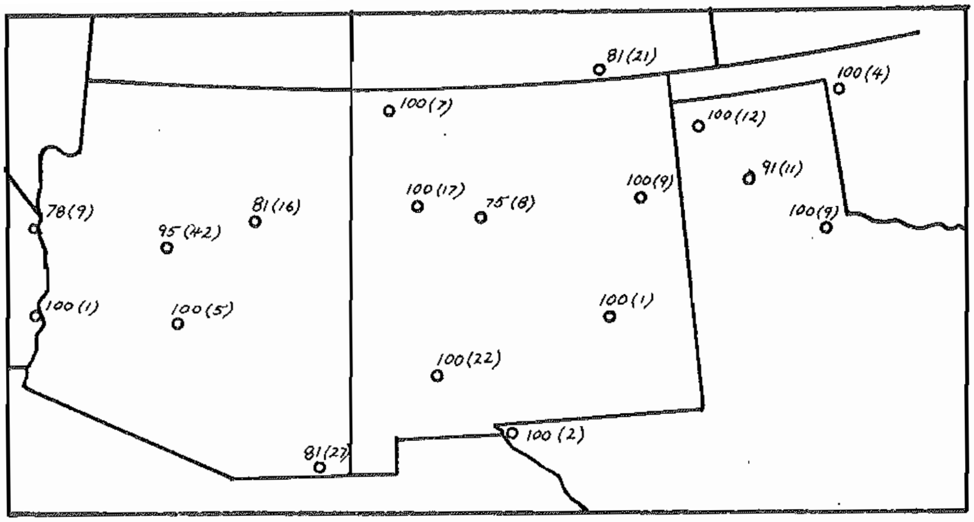


Figure 38. Percentage of reported thunderstorms detected by radar and (in parentheses) actual number reported 1 Aug.-31 Oct., 1969.

selected were scattered throughout the area of coverage and at every point the consistency of detection was very high. It is believed that the 9% not detected were, in some cases, those reported in the early stages of vertical development that had not yet attained the height required for detection but were detected subsequently.

3. Conclusions. When considering the value of ARTC radars in detecting thunderstorms, it is necessary not only to compare known storms in the vast open areas of this section of the country where weather data are not available. Figure 39 illustrates the radar detection of strong cells in areas such as these. Every ABQ RAREP of 6 Aug. 1969 indicated moderate to strong cells. El Paso forecasts called for thunderstorms with strong gusty surface winds and the Albuquerque WSFO issued a heavy rain statement with flash flooding in Albuquerque solely on the basis of the RAREPS.

There is no doubt that overshooting, terrain blocking and anti-clutter circuits will make their presence known when future studies pertaining to rain and snow are made. However, most of the important weather will be detected by the ARTC radars. What is being detected on ARTC radars at Albuquerque will, as in

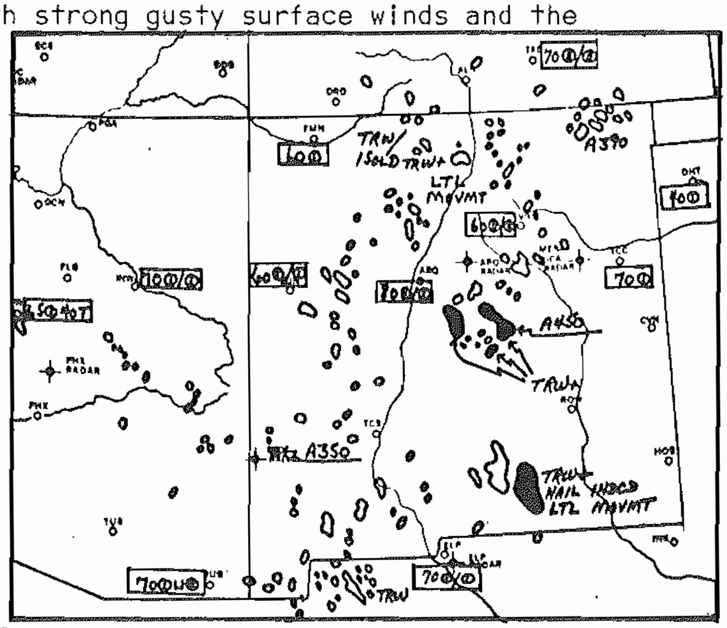


Figure 39. ABQ-ARTC RAREP - 2227Z - 6 Aug.'69

the past, assist in the issuance of general public advices, statements and warnings as well as aviation advisories for the area. During the period of operation from 10 Jan. 1969 to 31 Oct. 1969, a span of 294 days, 249 days or 85% were days when weather targets were detected.

VI. OPERATIONAL METHODS AND SERVICES

A. OBSERVATIONS.

1. Schedule. Regular observations are made and transmitted on an hourly basis, twenty-four hours per day.

2. Data Extraction. With the radarscope tuned for best presentation of weather echoes, precipitation targets are traced in detail onto a transparent overlay. The overlays, 14 inches in diameter, are specially designed for each radar and depict a map view of the area of coverage.

Upon completion of tracing the echo patterns from each of the six scopes, the observer obtains from the Watch Supervisor any information from pilots that would more adequately describe the weather situation. Seven telephones are provided expressly for the use of weather personnel. One is located in the weather office with an additional one placed on each of the six radar consoles. It is felt that dealing only with the Watch Supervisor in collecting PIREPS serves two purposes. It keeps him abreast of the weather situation over his area of responsibility and precludes the necessity of involving several controllers who may be working aircraft at the time.

The observer also scans the appropriate weather sequence for information that will aid in his analysis of the weather radar echoes.

3. Compositing of Echoes. Data extracted from the radar scopes are now composited onto a single chart by use of an optical reducer. The chart is then annotated to reflect type and intensity of precipiration, information received from pilots such as tops, direction and speed of movement, information pertaining to intensification or dissipation, and any additional information that it is felt will assist the users.

4. Dissemination. The composite map is transmitted via facsimile to the Salt Lake City Center which acts as net control and to WSFO's at Albuquerque, Fort Worth, and Phoenix; to El Paso WSO, Kirtland Air Force Base Weather Station, the Palmdale, California Center and to Mercury, NV. Radar reports are also sent hourly on the "RAWARC" teletypewriter circuit.

5. Special Observations. Special observations are taken on an unscheduled basis and transmitted to WSFOs concerned whenever it is felt that the weather dictates special attention. In this case the transparent overlay is taken directly from the scope, annotated, and transmitted via

facsimile. On many occasions on the basis of radar weather alone, issuance of general public advises, statements and warnings as well as aviation advisories for the area have been issued.

6. Cumulative Precipitation Chart. The cumulative precipitation chart is a significant and highly useful by-product of the hourly composite maps.

After each hourly composite from the six radarscopes has been prepared, the new areas of activity are traced onto a cumulative echo chart. Starting time for the chart is the 13Z observation - about the average diurnal minimum of convective activity. Hence, echoes logged on the cumulative (time composite) map represent a pattern for one convective day. A sample chart is shown in fig.40. Transmission of this map is made at 2330Z and 1130Z to show 12-hr and 24-hr areal coverage. Users see at a glance the areal extent and pattern of radar return.

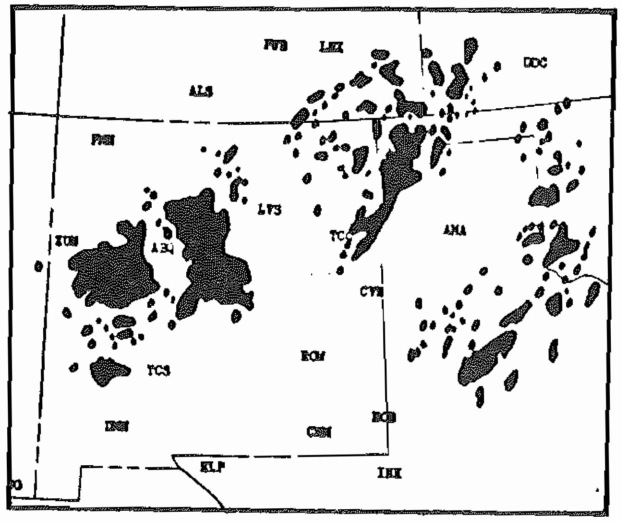


Figure 40. Time Composite

Forecasters are enthusiastic over its usefulness for analysis, for briefing, and summary preparation. Among user groups are forestry interests who not infrequently dispatch survey flights over reported areas of activity. The charts are transmitted via facsimile.

B. OPERATIONAL SERVICES

1. For FAA

a) ARTC Center. Operational services performed by the weather radar unit for the Center consist primarily of briefing and of informing the Watch Supervisor of thunderstorm activity in the close proximity of one or more of his radar sites. Briefings conducted twice daily at 0700 and 2000 Local Time, involve a large map of the area of responsibility depicting the general weather trend, terminal areas where low ceilings are likely to exist, information pertinent to turbulence, icing, freezing levels, location and effects of jet streams and the outlook, all presented in much the same format as the Area Forecast. In addition, the latest surface map is colored for enhanced legibility and to emphasize significant features.

The morning briefing is not face-to-face. The maps are put on display in the Control Room and the briefing is recorded on a two minute tape for use by the controllers. The tape is continuous and the briefing can be obtained by dialing the proper number within the "300 system". The afternoon briefing does include a face-to-face briefing of the Watch Supervisor and Crew chiefs working the evening watch.

The second service provided to the Center involves the operation of the Center complex. If thunderstorm activity is threatening or imminent, the Watch Supervisor is advised. If he deems it appropriate, he will have the power source for the complex switched from commercial to standby generator. This ensures that vital Center functions will not be interrupted.

b) FSS. During peak periods of activity at the Flight Service Station located at the Albuquerque International Airport, the WSFO, Albuquerque, provides to the FSS, for display and pilot briefing, all facsimile transmissions made by the radar unit.

2. FOR WSFOs ALBUQUERQUE, PHOENIX AND FORT WORTH, AND WSO EL PASO.

a) Public Service. All radar services to the general public are channeled through the WSFOs at Albuquerque, Fort Worth and Phoenix, and the El Paso WSO. The general public is best served through the routine forecasts, special warnings, and advisories, all of which reflect the radar weather input. The radar presentations are watched carefully for significant developments which may lead to severe weather. This is particularly true when a severe weather watch has been issued in the radar surveillance area or when the weather charts show a potential for such develppment. When echoes are detected under these conditions, the forecast offices are alerted via telephone and in addition to regular hourly composite charts, special overlays are prepared and transmitted via facsimile.

b) Aviation Services. Radar weather service to the Aviation Forecaster is similar to that for the general public discussed earlier. Significant weather echo patterns are watched closely and, if warranted, brought to his attention. Special overlays transmitted via facsimile have resulted in the issuance of aviation advisories ("SIGMETS") on numerous occasions. Radar provides a service to aviation in general through the issuance of hourly radar charts over national facsimile and teletypewriter circuits. Standard briefing services are enhanced through the availability of this information.

c) Fire Weather Services. Fire Weather Forecasters are assigned to the WSFO, Albuquerque. The composited activity chart and, upon request, special detailed overlays from one or more radars are provided to the fire-weather staff. Amplifying remarks are included to indicate direction of movement, intensity, intensification or dissipation, and trend of activity. Forestry interests, on the basis of radar information, often dispatch survey flights to the reported area.

d) Hydrology. In spite of the limitations of ARTC radars with regard to measuring precipitation intensity, considerable use is made of the radar data. Services to the hydrologist fall into two general categories:

1. Flash-flood potential.
2. Radar briefing during general flooding conditions.

The flash-flood program involves the early detection of potential flash flood situations and advising the appropriate WSO and/or WSFO responsible for issuing statements, watches, and warnings.

Under conditions which produce general flooding on river basins, frequent briefings and special radar overlays are provided.

During the month of August 1971, the Phoenix WSFO had occasion to issue 55 flash-flood statements, 16 watches, and 15 warnings. These actions took place on all but three days of the month and most were based upon radar data from the Albuquerque ARTCC. Feedback from local users, radio stations, etc., showed public acceptance and appreciation of the new warning program..

C. FUTURE IMPROVEMENT TO WEATHER PRODUCT

It is expected that the computerization of the Center, which is progressing rapidly, will afford a large bonus to the ARTC radar weather input. The bonus will come in the form of a contoured display and thereby reduce the present subjectivity in assigning rainfall intensities. Also, much of the processing of radar weather graphic presentations will be automated.

VII. CONCLUSION

It has been the intention throughout this report to provide evidence that ARTC radars are a very effective tool for use in gathering weather intelligence. Although the ARTC radars were not originally designed to detect weather, they have excellent capabilities for this purpose. This is not to say that the WSR-57 does not have advantages; however, one big advantage belongs to the ARTC radars in that they provide a tremendous amount of coverage while detecting most of the important weather.

Meteorologists using the product of the unit are happy with the program, it is economically sound, and the NWS/FAA relationship is excellent. All in all, the program has exceeded expectations.

VIII. ACKNOWLEDGMENTS

I would like to express my sincere thanks to the personnel of FAA who have always been eager to help and who have made the operation possible. Charles Crouch and the radar staff at WSO Amarillo, Texas made the comparative study possible by furnishing WSR-57 photographs. Portions of Section V are based on a study in 1970 by Mr. Wendell Logan, now at WSO Amarillo. Jack Teague, former Regional Radar Meteorologist (now deceased) rendered valuable assistance, and George Gregg, Meteorologist in Charge at WSFO Albuquerque, provided photographs of the facility in addition to encouragement to finish the study.